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07/05/00

PATENT
Atty. Dkt. AMAT/2813.d1/SILICON/JB
Express Mail No. 6435691472245

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Assistant Commissioner of Patents
Box PATENT APPLICATIONS
Washington, D.C. 20231

CERTIFICATE OF MAILING 37 C.F.R. 1.10	
I hereby certify that this correspondence is being deposited on <u>7-5</u> , 2000, with the United States Postal Service as Express Mail No. <u>6435691472245</u> in an envelope addressed to: Assistant Commissioner of Patents, Box PATENT APPLICATION, Washington, D.C. 20231.	
<u>7-5-2000</u> Date	<u>Ben Malachuk</u> Signature

1c867 U.S. PTO
09/610237
07/05/00

REQUEST FOR FILING A PATENT APPLICATION UNDER 37 C.F.R. 1.53(b)

This is a request for a filing a continuing application procedure, 37 CFR 1. 53(b) for:

- ☐ Continuation
- ☒ Divisional
- ☐ Continuation-in-part
- ☐ attached is an amendment for added subject matter
- ☐ Continuing application to permit consideration of an information disclosure statement under 37 CFR 1.97

Enclosed is a copy of the latest inventor-signed prior application, including a copy of the oath or declaration showing the original signature or an indication it was signed. I hereby verify that the papers are a true copy of the latest signed prior application serial number 09/096,728, and further that all statements made herein of my own knowledge are true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issuing thereon.

- ☒ A preliminary amendment is enclosed
- ☐ Formal drawings are enclosed

09610237 070500

PARTICULARS OF PRIOR APPLICATION

Application Serial No.: 09/096,728

Filed: 06/11/98

Title: Chamber Having Improved Process Monitoring Window

(a) | x | This application discloses and claims only subject matter disclosed in the prior application whose particulars are set out above, and the inventor(s) in this application are:

| x | the same

| | less than those named in the prior application, and it is requested that the following inventor(s) identified above for the prior application be deleted:

(b) | | This application discloses and claims additional disclosure by amendment and a new declaration or oath is being filed. With respect to the prior application whose particulars are set out above, the inventor(s) in this application are:

| | the same

| | Add the following additional inventor(s):

(c) | | The inventorship for all the claims in this application is:

| | the same

| | not the same; and an explanation, including the ownership of the various claims at the time the last claimed invention was made, is submitted.

IDENTIFICATION OF CLAIMS FOR FURTHER PROSECUTION

- | x | The fees to be charged are to be based on the number of claims remaining as a result of the:
- | | attached preliminary amendment
 - | | unentered amendment filed under 37 CFR 1.116 in the prior application, which is now repeated.
 - | | the claims as on file in the prior application
 - | x | the claims 1-58 of the present application.
 - | | cancel in this application original claims.

FEE CALCULATION (37 CFR 1.16)

	NUMBER OF CLAIMS FILED	LESS NUMBER PAID BY BASIC FEE	NUMBER OF EXTRA CLAIMS (Not less than zero)	LARGE ENTITY FEE
Basic Fee				\$690
Total Claims	58	- 20 = 38	38 x 18 =	\$684
Independent C l a i m s	9	- 3 = 6	6 x 78 =	\$468
First Presentation of Multiple Dependent Claims + 250				-0-
Total Filing Fee Calculation:				\$1842

- | | A verified statement to establish small entity status under 37 CFR 1.9 and 1.27
- | | is enclosed
 - | | was filed in prior application number --- and such status is still proper and desired (37 CFR 1.28(a))

FEE PAYMENT BEING MADE AT THIS TIME

- ☐ | No filing fee is submitted
- ☒ | The Commissioner is hereby authorized to charge the Filing Fee of \$1,842.00 to **Deposit Account 50-1074.**
- ☐ | Recording assignment (\$40) [37 CFR 1.21(h)]
- ☐ | Petition fee for filing by other than all the inventors or person not the inventor where inventor refused to sign or cannot be reached (\$130) [37 CFR 1.47 and 1.17(h)]
- ☐ | Processing and retention fee (\$130) [37 CFR 1.53(d) and 1.21(l)]
- ☐ | A check in the amount of: \$ _____ (A duplicate copy of this request is enclosed)

AUTHORIZATION TO CHARGE ADDITIONAL FEES

- ☒ | The Commissioner is hereby authorized to charge the following additional fees which may be required by this paper and during the entire pendency of this application, to **Deposit Account 50-1074.**
 - ☒ | 37 CFR 1.16(a), (f) or (g) (filing fees)
 - ☒ | 37 CFR 1.16(b), (c) and (d) (presentation of extra claims)
 - ☒ | 37 CFR 1.16(e) (surcharge for filing the basic filing fee and/or declaration on a date later than the filing date of the application)
 - ☒ | 37 CFR 1.17 (application processing fees)
 - ☐ | 37 CFR 1.18 [issue fee at or before mailing of Notice of Allowance, pursuant to 37 CFR 1.311(b)]

INSTRUCTIONS AS TO OVERPAYMENT

- ☒ | **Credit Deposit Account No. 50-1074**

PRIORITY--35 U.S.C. 119

- ☐ | Priority of application Serial No. _____ filed on _____ in _____ is claimed under 35 U.S.C. 119.

| | The certified copy has been filed on _____ in prior U.S. application Serial No. _____, which prior application was filed on _____.

| | Certified copy will follow.

RELATE BACK--35 U.S.C. 120

| | Amend the specification by inserting before the first line the sentence:

"This is a | | continuation | | divisional | | continuation-in-part
of copending application(s)

| | Serial No. _____, filed on _____.

| | International Application _____ filed on _____ and which
designated the U.S.

ASSIGNMENT

|X| The prior application is assigned of record to: Applied Materials, Inc.

| | An assignment of the invention to: _____, is attached.

| | Form PTO 1595 (Recordation Form Cover Sheet) is also attached (**in duplicate**)

POWER OF ATTORNEY

|X| The power of attorney in the prior application is to:

Michael L. Sherrard	Registration No. 28,041
Peter J. Sgarbossa	Registration No. 25,610
Donald Verplancken	Registration No. 33,217
Lawrence Edelman	Registration No. 25,226
Michael B. Einschlag	Registration No. 29,301
Raymond Kam-On Kwong	Registration No. 37,165
James C. Wilson	Registration No. 35,412
Robert W. Mulcahy	Registration No. 25,436
Sarah J. Brashears	Registration No. 38,087
Ashok K. Janah	Registration No. 37,487
Guy V. Tucker	Registration No. 45,302

- ☒ The power appears in the original papers in the prior application submitted herewith.
- ☐ The power does not appear in the original papers, but was filed on _____.
- ☐ A new power has been executed and is attached.
- ☒ Send correspondence to:

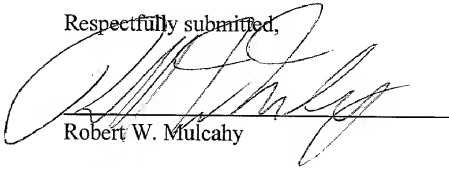
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- ☒ Direct telephone calls to:

Firm Name: Janah and Associates
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Date: 7/5/00

Respectfully submitted,


Robert W. Mulcahy

Registration No. 25,436
APPLIED MATERIALS, INC.
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Attorney for Applicant

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	Group Art Unit: unknown
Grimbergen, et al.	Examiner: unknown
Serial No.: unknown	Attorney Docket No. 2813.d1/SILICON/JB
Filing Date: herewith	June 29, 2000 San Francisco, California
For: CHAMBER HAVING PROCESS MONITORING WINDOW	

PRELIMINARY AMENDMENT

Box Patent Application
Assistant Commissioner for Patents
Washington, D.C. 20231

Dear Examiner:

Enclosed is a preliminary amendment for the herewith filed divisional application.

Express mailing label number EL356914122US

Date of Deposit 7-5-2000

I hereby certify that this paper is being deposited with the United States Postal Service "Express Mail Post Office to Addressee" service under 37 CFR 1.10 on the date indicated above and is addressed to: Box Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

BETH MULLCAHY
Name of Person Mailing Paper

Beth Mulcahy
Signature of Person Mailing Paper

IN THE SPECIFICATION:

On page 12, line 16, delete "thorough" and insert -through- therefor.

On page 16, line 12, insert -is- after "This".

IN THE DRAWINGS:

Attached please find proposed drawing corrections. The corrections are shown in red ink.

REMARKS

Applicant requests entry of these amendments which are fully supported by the specification and original claims and add no new matter. The amendments are being made to correct minor errors as in the parent application.

CONCLUSION

The Examiner is respectfully requested to enter the present amendments and to allow the pending claims. Should the Examiner have any questions, the Examiner is requested to call the undersigned representative of the Applicant.

Respectfully submitted,

JANAH & ASSOCIATES
A PROFESSIONAL CORPORATION

Dated: June 29, 2000

By: 
Ashok K. Janah, Reg. No. 37,487

Please direct telephone calls to:

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Patent Counsel
APPLIED MATERIALS, INC.
P.O. Box 450A
Santa Clara, California 95052

United States Patent Application for:

**CHAMBER HAVING
PROCESS MONITORING WINDOW**

**Inventors: MICHAEL N. GRIMBERGEN
 XUE-YU QIAN**

Docket No: 2813.D1/SILICON/JB

Certification under 37 C.F.R. 1.10

I hereby certify that this New Application and the documents referred to as enclosed therein are being deposited with the United States Postal Service on this date 4-5-2000 in an envelope as "Express Mail Post Office to Addressee" Mailing Label Number EL3569473245 addressed to: Box Patent Application, Assistant Commissioner for Patents, Washington, D.C. 20231.

BETH MURPHY
Name of Person Mailing Paper

Beth Murphy
Signature of Person Mailing Paper

CHAMBER HAVING PROCESS MONITORING WINDOW

CROSS-REFERENCE

This application is a divisional application of U.S. Patent Application Serial Number 09/096,728, filed on June 11, 1998, which is incorporated herein by reference in its entirety.

BACKGROUND

The present invention relates to a process chamber and process monitoring window.

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In integrated circuit fabrication, layers of semiconductor, dielectric, and conductor materials, such as for example, polysilicon, silicon dioxide, aluminum and copper layers are deposited on a substrate and subsequently processed, for example, by etching with an etchant plasma, to form active devices. The layers are deposited on the substrate in a process chamber by processes such as chemical vapor deposition (CVD), physical vapor deposition (PVD), thermal oxidation, ion implantation and ion diffusion. After deposition, a resist layer of photoresist or hard mask is applied on the deposited layer and patterned by photolithography. Portions of the deposited layers lying between the resist features are etched using RF or microwave energized halogen and other reactive gases to form etched features.

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In these fabrication processes, it is often desirable to monitor in-situ the process being performed on the substrate by a process monitoring system. For example, in CVD and PVD processes, it is desirable to stop the deposition process after a desired thickness of a layer is deposited. In etching processes, endpoint detection methods are used to prevent overetching of layers that are being etched. Typical process monitoring methods, include for example, plasma emission analysis, ellipsometry, and interferometry. In plasma emission analysis, an emission spectra of a plasma

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is measured to determine a change in chemical composition that corresponds to a change in the layer being processed, as for example, taught in U.S.

Patent No. 4,328,068 which is incorporated herein by reference. In

ellipsometry, a polarized light beam is reflected off a layer on the substrate

5 and analyzed to determine a phase shift and a change in magnitude of the reflected light that occurs with changes in the thickness of the layer, as for example disclosed in U.S. Patent Nos. 3,874,797 and 3,824,017, both of which are incorporated herein by reference. In interferometry, a non-

10 polarized light beam is reflected off the layer and analyzed to determine a change in magnitude of the reflected light that occurs due to interference of reflected light components from the top and bottom surfaces of the layer on the substrate, as for example, described in U.S. Patent No. 4,953,982, issued September 4, 1990, which is incorporated herein by reference. These process monitoring methods require a high strength optical transmission
15 signal through the window and also require viewing or signal sampling of relatively large surface area of the substrate.

A typical process monitoring system comprises an optical sensor system for detecting and measuring light emissions or light reflections
20 through a window in a wall of the process chamber. The window is transparent to particular light wavelengths to allow light to be transmitted in and out of the chamber while maintaining a vacuum seal with the chamber. When monitoring a layer on a substrate, the transparent window is positioned in the chamber wall in direct line of sight of the substrate.
25 Process monitoring windows are typically constructed from quartz which is resistant to high temperatures and are sealed to the chamber surface with O-ring seals positioned along their edges.

However, in many deposition and etching processes, a thin
30 cloudy film of residue deposits and byproducts are deposited on the process monitoring window as substrates are being processed in the chamber. The process residues are deposited on the window at rates often in excess of 1 micron in 25 to 50 hours of process operation. The deposited film of process residue changes the properties or intensity of the light transmissions

passing through the window. For example, in plasma emission analysis, the residue deposits selectively filter out particular wavelengths of light from the optical emission spectra of the plasma resulting in errors in process monitoring measurements. In ellipsometry, the residue deposits change the state of polarization of the light beam transmitted or reflected through the window causing erroneous ellipsometric measurements. As another example, in interferometry, the deposits absorb and lower the intensity of the light passing through the window resulting in a lower signal-to-noise ratio.

To avoid these problems, conventional processing monitoring windows are periodically replaced or cleaned to remove the residue deposits formed on the windows. For example, in typical etching processes, after etching a certain number of wafers, or operating cumulatively for about 10 hours, the chamber is opened to the atmosphere and cleaned in a "wet-cleaning" process, in which an operator uses an acid or solvent to scrub off and dissolve the deposits accumulated on the window and chamber walls. After cleaning, the chamber is pumped down for 2 to 3 hours to outgas volatile acid or solvent species, and a series of etching runs are performed on dummy wafers. In the competitive semiconductor industry, the downtime of the chamber during such cleaning processes can substantially reduce process throughput and increase processing costs per substrate. Also, manually performed wet cleaning processes are often hazardous, and the quality of cleaning varies from one session to another.

One approach to solving the residue deposition problem uses a recessed window positioned in a long tube that opens into the chamber. Because the process gas or plasma in the chamber has to travel through the length of the tube before reaching the recessed window, the deposition of process residues on the surface of the recessed window inside the tube is markedly reduced. However, the high aspect ratio (length/diameter) of the elongated tube makes it difficult to monitor a sufficiently large sampling area inside the chamber, and reduces the total light flux. This limits the accuracy of the process monitoring systems during processing of a batch of substrates or sometimes even for a single substrate. In addition, the elongated tube

takes up a large amount of space outside the chamber, which is undesirable in tight clean room spaces, and the tube is also difficult to fit in-between other components of the process chamber.

5 In another solution, the process monitoring window is selectively heated to prevent deposition of process residue deposits, as described in commonly assigned U.S. Patent No. 5,129,994, to Ebbing et al., issued on July 14, 1992. However, while suitable for certain types of processes, heating does not prevent all forms of residues from condensing and depositing on the window, and in certain processes, heating can actually
10 increase the rate of deposition of process residue on the window.

 In yet another approach, photosensitive equipment is used to sample signals of the light emissions or reflections from the
15 chamber/substrate and mathematically manipulate the sampled data to increase the signal to noise ratio of the light signal passing through a cloudy window, as for example, described in U.S. Patent No. 5,738,756 to Liu, issued on April 14, 1998. However, complex mathematical manipulations can delay process response times. In etching processes, even a small time
20 delay can result in undesirable charging or lattice damage of the underlying layers, especially for underlying polysilicon layers. In addition, these processes are not always able to increase the signal to noise ratio by a sufficient amount to provide a discernible signal. If the signal is too small, the fabrication process may never be terminated, and if it is too large, the
25 process may be prematurely terminated.

 The process residues deposited on windows are a particular problem when monitoring etching processes in which etching of a thick overlayer has to be stopped before etching through a relatively thin
30 underlayer. For example, the aggressive halogen containing gases etchant gases that are used to etch a relatively thick layer will often uncontrollably etch through or damage any thin underlayers, without an accurate and reliable process monitoring system. This is especially a problem when etching a polysilicon overlayer to expose a thin gate oxide underlayer. After

the polysilicon etching process, it is desirable for the remaining thickness of the gate oxide layer to be very close to a nominal and predetermined thickness. As the gate oxide layer becomes thinner, it is more difficult to accurately etch through the polysilicon overlayer without overetching into the gate oxide layer. It is further desirable to stop the etching process on the gate oxide layer without causing charge or lattice damage to underlying silicon by exposed the silicon to the energetic etchant plasma. This type of process control is only possible with a reliable and consistently performing process monitoring system.

Thus it is desirable to have a chamber and process monitoring system that allows monitoring of processing of substrates in the chamber, without excessive signal loss during continued processing of the substrate. It is further desirable to have a process monitoring window that prevents or reduces deposition of process residue on its surfaces and exhibits a low rate of erosion in reactive halogen gases and plasmas. It is also desirable to have a method of monitoring processing of a substrate that provides accurate and repeatable processing results, especially for etching thick overlayers on thin underlayers.

SUMMARY

In one aspect of the invention, a substrate processing chamber comprises a support, a gas distributor, a gas energizer, a wall comprising a radiation transmitting portion, a mask overlying the radiation transmitting portion, the mask having an aperture, and an exhaust, whereby a substrate held on the support may be processed by process gas distributed by the gas distributor, energized by the gas energizer, and exhausted by the exhaust, and whereby the mask is adapted to reduce deposition of process residue on the radiation transmitting portion and whereby radiation may be transmitted through the aperture of the mask and the radiation transmitting portion.

In another aspect of the invention, a substrate processing chamber comprises a support having a receiving surface capable of

supporting a substrate, a gas distributor capable of providing process gas in the chamber and a gas energizer that is capable of coupling energy to the process gas, a radiation transmitting portion that allows radiation to be transmitted therethrough to monitor processing of the substrate, means
5 extending into the interior of the chamber for reducing deposition of process residue from process gas on the radiation transmitting portion, and an exhaust capable of exhausting process gas from the chamber.

In another aspect of the invention, a substrate processing
10 chamber comprises a support, a gas distributor, a gas energizer, a radiation transmitting portion comprising a mask with a plurality of apertures, and an exhaust, whereby a substrate held on the support may be processed by process gas distributed by the gas distributor, energized by the gas energizer, and exhausted by the exhaust, and whereby radiation may be transmitted
15 through the radiation transmitting portion.

In another aspect of the invention, a substrate processing
comprises a support, a gas distributor, a gas energizer, a wall comprising an aperture, the aperture having an aspect ratio selected to reduce deposition of
20 process residue, an exhaust, and a process monitoring system, whereby a substrate held on the support may be processed by process gas distributed by the gas distributor, energized by the gas energizer, and exhausted by the exhaust, and whereby radiation may be transmitted through the aperture to the process monitoring system.

25 In another aspect of the invention, a window capable of being mounted on a process chamber comprises a radiation transmitting portion and an overlying mask with an aperture, whereby the mask is adapted to reduce deposition of process residue on the window and whereby radiation
30 may be transmitted through the window when a substrate is processed in the process chamber.

In another aspect of the invention, a method of processing a substrate in a process chamber comprises the steps of placing the substrate

in the process chamber, maintaining first process conditions in the process chamber to process the substrate, the first process conditions including providing an energized process gas in the process chamber, masking a radiation transmitting portion in a wall of the process chamber to reduce
5 deposition of process residue on the radiation transmitting portion and measuring a property of radiation transmitted through the radiation transmitting portion, and changing the first process conditions to second process conditions in relation to the measured property of the transmitted radiation.

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In another aspect of the invention, a method of processing a substrate in a process chamber comprises the steps of placing the substrate in the process chamber, maintaining process conditions in the process chamber to process the substrate, the process conditions including providing
15 an energized process gas in the process chamber, and maintaining a magnetic flux across a portion of a wall of the process chamber.

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In another aspect of the invention, a method of processing a substrate in a process chamber, the method comprises the steps of placing
the substrate in the process chamber, maintaining first process conditions in the process chamber to process the substrate, the first process conditions including providing an energized process gas in the process chamber, maintaining a magnetic flux across at least a portion of a radiation
transmitting portion in a wall of the process chamber, measuring a property
25 of radiation transmitted through the radiation transmitting portion, and changing the first process conditions to second process conditions in relation to the measured property of the transmitted radiation.

25

In another aspect of the invention, a method of processing a
30 substrate in a process chamber comprises the steps of placing the substrate in the process chamber, maintaining process conditions in the process chamber to process the substrate, the process conditions including providing an energized process gas in the process chamber, and electrically biasing a portion of a wall of the process chamber.

DRAWINGS

These and other features, aspects, and advantages of the present invention will be better understood from the following drawings, description and appended claims, which illustrate examples of the invention. While the description and drawings below illustrate exemplary features of the invention, it is to be understood that each of the features can be used in the invention in general, not merely in the context of the particular drawings, and the invention includes any combination of these features.

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Figure 1 is a schematic sectional view of an embodiment of a process chamber according to the present invention showing a window and overlying mask;

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Figure 2 is a schematic sectional view of another process chamber according to the present invention;

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Figure 3a is a schematic sectional view of yet another process chamber having a tilted window and overlying mask according to the present invention;

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Figure 3b is a schematic top view of one embodiment of a mask according to the present invention;

Figure 4a is a schematic side view of another embodiment of a window and overlying mask;

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Figure 4b is a schematic top view of the window and overlying mask of Figure 4a;

Figure 5 is a graph showing the net deposition of process residue as a function of the aspect ratio of different sized apertures in a test mask;

Figure 6a is a partial schematic side view of another process chamber embodiment showing a magnetic field source for maintaining a magnetic flux across the window;

5 Figure 6b is a top view of the window of Figure 6a showing a permanent magnet having a pair of facing magnetic poles with an aperture therebetween;

10 Figure 6c is a schematic top view of the window of Figure 6b showing the magnetic flux lines across the aperture;

Figure 6d is a schematic top view of window and a magnetic field source comprising a plurality of magnetic poles around an aperture;

15 Figure 7 is a schematic sectional view of another process chamber embodiment with a window and an electrical field source comprising an electrode behind the window;

20 Figure 8a is a partial schematic side view of another process chamber embodiment with a window and an electrode behind the window;

Figure 8b is a schematic top view of the electrode of Figure 8a showing an array of eddy current reducing slots;

25 Figure 8c is a schematic top view of another embodiment of the electrode and eddy current slots; and

Figure 8d is a schematic top view of another embodiment of the electrode and eddy current slots.

30

DESCRIPTION

The semiconductor processing apparatus 20 and process monitoring system 25 of the present invention is useful for fabricating

integrated circuits on a semiconductor substrate **30**. The processing apparatus **20**, as schematically illustrated in Figure 1, comprises a process chamber **35** having a process zone **40** for processing the substrate **30**, and a support **45** for supporting the substrate **30** in the process zone **40**. An electrostatic chuck **50** holds the substrate **30** on the support **45** during processing of the substrate **30**. The process zone **40** surrounds the substrate **30** and typically comprises a volume of about 10,000 to about 50,000 cm³. The process chamber **35** can comprise a flat rectangular shaped ceiling **55**, or a ceiling which is arcuate, conical, dome-shaped, or multi-radius dome-shaped. Preferably, the ceiling **55** is dome-shaped to enable a gas energizer **60** to uniformly couple power across the entire volume of the process zone **40** thereby providing a more uniform density of energized gaseous species across the substrate surface than a flat ceiling **55**.

Process gas is introduced into the process chamber **35** through a gas distribution system **65** that includes a process gas source **70**, a gas flow control valve **75**, and a process gas distributor **80**. The gas distributor **80** can comprise gas outlets located at or around the periphery of the substrate **30** (as shown), or a showerhead mounted on the ceiling **55** of the process chamber **35** with outlets therein (not shown). Spent process gas and etchant byproducts are exhausted from the process chamber **35** through an exhaust system **85** (typically including vacuum pumps **90** such as a 1000 liter/sec roughing pump and a 1000 to 2000 liter/sec turbomolecular pump) capable of achieving a minimum pressure of about 10⁻³ mTorr in the process chamber **35**. A throttle valve **95** is provided in the exhaust system **85** to control the flow of spent process gas and the pressure of process gas in the process chamber **35**.

The gas energizer **60** couples electromagnetic energy to the process gas to form energized gaseous species. In the embodiment shown in Figure 1, the gas energizer **60** comprises an inductor antenna **100** encircling the process chamber **35** to energize the process gas directly in the process zone **40** through inductive coupling by applying an RF current to the inductor antenna **100**. Alternatively, the process gas is energized by capacitive

coupling by applying an RF voltage to a gas energizer **60** comprising process electrodes formed by the support **45** and the ceiling **55** of the process chamber **35**. In the process chamber **35** of Figure 1, the ceiling **55** comprises a semiconducting material to function both as a process electrode
5 for capacitively coupling RF energy into the process chamber **35**, and as a window for inductively coupling RF energy into the process chamber **35**. The frequency of the RF energy applied to the inductor antenna **100**, or process electrodes **45,55**, is typically from about 50 KHz to about 60 MHz, and more typically about 13.56 MHz. Preferably, the RF voltage applied to
10 the process electrodes **45,55** by an electrode power supply **102** is at a bias power level of from about 1 to about 500 Watts; and the RF current applied to the inductor antenna **100** by a coil power supply **104** is at a source power level of from about 500 to about 2000 Watts.

15 Figure 2 shows an alternative embodiment of the processing apparatus **20** in which the process gas is energized or activated by the gas energizer **60** in a remote chamber **105**, such as a tube or cylinder adjacent to the process chamber **35**. By "remote" it is meant that the center of the remote chamber **105** is at a fixed upstream distance from the center of the
20 process chamber **35**. The remote chamber **105** comprises a gas energizer **60** that couples microwaves or other frequencies of electromagnetic energy from a suitable source into a remote zone **110**, to activate process gas introduced into the remote chamber **105**. A suitable microwave source comprises a microwave applicator **115**, a microwave tuning assembly **120**,
25 and a magnetron microwave generator **125** and is typically operated at a power level of from about 200 to about 3000 Watts, and at a frequency of from about 800 MHz to about 3000 MHz.

In yet another embodiment of the processing apparatus **20**, the
30 uniformity and density of ions in the energized process gas can be enhanced using electron cyclotron resonance or a magnetic field generator **127**, such as permanent magnets or electromagnetic coils **129**. For example, a MxP+ OXIDE ETCH chamber, commercially available from Applied Materials Inc., Santa Clara, California, and generally described in commonly assigned U.S.

Patent No. 4,842,683, issued June 27, 1989, which is incorporated herein by reference. Referring to Figure 3a, process gas is introduced into the process zone **40** and energized by an electric field generated by applying a RF power to the support **45** and the ceiling **55** or sidewalls of the process chamber **35**. Preferably, the magnetic field comprises a rotating magnetic field with the axis of the field rotating parallel to the plane of the substrate **30**. The magnetic field in the process chamber **35** should be sufficiently strong to increase the density of the ions formed in the energized process gas, and sufficiently uniform to reduce charge-up damage to features formed on the substrate **30** such as CMOS gates. Generally, the magnetic field as measured on a surface of the substrate **30** is less than about 500 Gauss, more typically from about 10 to about 100 Gauss, and most typically from about 10 Gauss to about 30 Gauss.

The process monitoring system **25** monitors the progress of a process being performed in the process chamber **35** thorough a window **130** in the process chamber ceiling **55** or a wall that is transparent to light that is emitted from, or directed into, the process chamber **35**. The process monitoring system **25** is particularly useful for monitoring the progress of a layer being etched, and to prevent damaging an underlying layer on the substrate **30**. Suitable process monitoring systems **25** include detectors based on optical emission, ellipsometry, and interferometry. Optical emission detectors detect changes in the spectral lines of light spectra emitted by species in the energized process gas to detect changes in chemistry that would indicate the beginning of etching of the underlying layer. Ellipsometers project a light beam at an acute angle to the surface of the substrate **30** and detect a phase shift between portions of the light beam reflected off the top and bottom surfaces of a transparent film on the substrate **30**. An interferometer also reflects a beam of light off the top and the bottom surface of a transparent film on the substrate **30**. However, an interferometer determines the thickness of the film on the substrate **30**, by measuring the magnitude of constructive or destructive interference between the reflected light beams, and does not need to project the incident light beam at an acute angle relative to the surface of the substrate **30**. In fact,

typically the interferometer directs the light beam at nearly a right angle relative to the surface of the substrate **30**, i.e., at an angle of close to 90° . Unlike an optical emission detector, the interferometer detector can be used to detect and stop a semiconductor etching process before reaching an underlying layer below the layer being etched. Also, because the light beam is directed at nearly a right angle, the interferometer can be used for etching features having high aspect ratios, which would block the low angle beam of the ellipsometer. Thus it is generally preferred to use an interferometer system to detect the endpoint of an etch process performed in the process chamber **35**.

Referring to Figures 4a and 4b, a window **130** according to the present invention comprises a transparent plate **135** and an overlying mask **140** having at least one aperture **145** extending therethrough. The mask **140** covers the surface of the transparent plate **135** facing the inside of the process chamber **35** so that light can be transmitted through the transparent plate **135** and the aperture **145** of the mask **140** to monitor the process being conducted on the substrate **30**. The mask **140** covering the transparent plate **135** serves to reduce deposition of process residue, byproducts, and other deposits on the window **130**, thereby allowing accurate and reproducible monitoring of processes conducted on the substrate **30**. The light transmitted through the window **130** comprises plasma spectra for plasma emission analysis or light reflected from the substrate **30** that is used for process monitoring systems **25** based on interferometry or ellipsometry principles. The window **130** is shaped, sized, and located to allow an incident light beam **148a** transmitted therethrough to be incident on the substrate **30** at an angle that is sufficiently large to provide a near vertical incidence of the light near the center of the substrate **30**. Generally, the window **130** can comprise any shape including circular, oval, or polygonal shape.

The transparent plate **135** of the window is made of solid transparent material that is transparent to selected frequencies of electromagnetic radiation used in the process monitoring system **25**.

Preferably, the transparent plate **135** is transparent to ultraviolet, visible, and infrared light from a light source **150** used to provide the incident light beam **148a** for the endpoint detection system. To prevent attenuation of the incident light beam **148a** by scattering, both surfaces of the transparent plate

5 **135** are polished smooth with a peak-to-peak RMS roughness (i.e., the vertical distance between the peaks and valleys of the roughness on the polished crystal face) that is sufficiently small to allow light to be transmitted therethrough. Preferably, the peak-to-peak RMS roughness of the transparent plate **135** is less than about $1\text{ }\mu\text{m}$, and more preferably less than

10 about $0.1\text{ }\mu\text{m}$. The surface of the transparent plate **135** can be polished smooth by any suitable means, for example, by flame polishing or conventional lapping and/or ablating methods.

The transparent plate **135** is made of a ceramic monocrystalline

15 material that is a single crystal material or one that comprises a few (typically 10 or fewer) large crystals that are oriented in the same crystallographic direction, and is transparent to particular wavelengths of light or visible radiation. Preferably, the monocrystalline material comprises a ceramic, such as for example, one or more of Al_2O_3 , Si, SiO_2 , TiO_2 , ZrO_2 , or mixtures and

20 compounds thereof. The monocrystalline ceramic material is selected to exhibit high corrosion resistance in a particular plasma or other process environment. In a preferred embodiment, the transparent plate **135** comprises polished sapphire, which is a monocrystalline form of alumina that exhibits high chemical and erosion resistance in halogen plasma

25 environments, especially fluorine containing environments. Monocrystalline sapphire also has a high melting temperature that allows use of the window **130** at temperatures exceeding 1000°C , and preferably in excess of 2000°C .

In one embodiment, the transparent plate **135** is tilted at a

30 small angle relative to the plane of a surface substrate **30**, so that light reflected from the transparent plate **135** is not reflected back into the process monitoring system **25**, thereby allowing greater signal gain in process monitoring. A suitable angle of tilt is at least about 2 degrees, and more preferably, from about 2 to about 15 degrees. For example, Figure 3a

shows a tilted transparent plate **135** that is angled about 3 degrees relative to the plane of the substrate **30**. The tilted plate **135** is angled by raising one side or edge of the transparent plate **135** higher than the opposing side/edge of the transparent plate by providing a raised step **152** below an

5 edge of the transparent plate **135**. The step is sized depending on the angle of elevation or tilt that is desired and is typically from about 0.5 to about 5 mm depending on the diameter of the transparent plate **135**.

The mask **140** covering the transparent plate **135** serves to

10 reduce deposition of process gas byproducts formed in the process chamber **35** on the transparent plate **135**. The mask **140** is made of a material that is resistant to erosion by the process gas and/or the plasma formed from the process gas. Preferably, the mask **140** is made from a plasma resistant material comprising one or more of Al_2O_3 , SiO_2 , AlN , BN , Si , SiC , Si_3N_4 , TiO_2 ,

15 or ZrO_2 . Referring to Figure 4b, one embodiment of the mask comprises a thick disc of aluminum oxide that is shaped to cover substantially the entire exposed portion of the transparent plate **135** of the window. Preferably, when the transparent plate **135** comprises a disc, the mask **140** comprises a right cylinder that is shaped and sized to cover the surface of the disc. More

20 preferably, the mask **140** comprises disc having a raised central portion **153** with a surrounding annular lip **154**. The thickness of the raised central disc portion is preferably from about 0.5 mm to about 500 mm. The diameter of the raised central portion **153** of the mask is from about 50 mm to about 200 mm. The thickness of the annular lip **154** is from about 0.5 mm to

25 about 10 mm, and a smooth rounded edge forms the transition between the raised central disc and the annular lip **154**.

The mask **140** comprises at least one aperture **145** that allows a sufficient intensity of light to pass through the aperture to operate the

30 process monitoring system **25**, and that controls the access of energized process gas species to the transparent plate **135** of the window **130**. The cross-sectional area of the aperture **145** sufficiently large to allow a sufficiently large amount of light flux to ingress and egress from the process chamber **35**. The aperture **145** can be cylindrical, or polygonal in shape,

including triangular, hexagonal, square, and rectangular, of which hexagonal is preferred since it enables a plurality of apertures **145** to be more closely spaced allowing improved transmission of light into and out of the process chamber **35**. The aspect ratio of the aperture **145** controls the access of energized process gas species to the transparent plate **135** of the window **130**. Preferably, the aspect ratio of the aperture **145** is from about 0.25:1 to about 12:1.

In one embodiment, the aperture **145** is shaped and sized to limit or reduce access of the process gas to the transparent plate **135** and thereby prevent deposition of process gas byproducts and other deposits on the transparent plate **135**. This accomplished by making the aspect ratio of the aperture **145** (which is the ratio of the aperture's height to its diameter/width) sufficiently large or high to limit access of the neutral flux of process gas, and therefore access of the volatilized process gas byproducts that condense to form process residues, into the aperture **145** and onto the underlying transparent plate **135** of the window **130**. Preferably, the aspect ratio is from about 1:1 to about 12:1, and more preferably from about 3:1 to about 7.5:1.

In another embodiment, as illustrated in Figure 3b, the shape and size of the aperture **145** in the mask **140** is selected to reduce the accumulation of process residue on the underlying transparent plate **135** of the window **130** by a different mechanism. In this version, the aspect ratio of the aperture **145** is sufficiently small to allow ions of the energetic process gas to enter the aperture and etch away the process residues formed on a sidewall of the aperture **145** and/or on the surface of the transparent plate **135**. The aperture **145** in this embodiment generally has a larger sized diameter or width relative to its height to provide a relatively low aspect ratio. The low aspect ratio preferentially filters out energetic plasma species to allow a higher percentage of highly directional and energetic plasma species to enter into the aperture **145** and sputter-etch away the process residue deposited on the sidewalls of the aperture **145** and on the surface of

the transparent plate **135**. A suitable aspect ratio is from about 0.25:1 to about 3:1, and more preferably from about 0.5:1 to about 2:1.

The mask **140** can also comprise a plurality of apertures **145**,
5 and more preferably, an array of apertures as already described. Preferably, the total area of the aperture **145** is sufficiently large to transmit both an incident light beam **148a** and a reflected light beam **148b** or the desired level or intensity of plasma spectra flux for plasma emission analysis. Preferably, for process monitoring systems **25** comprising interferometry or ellipsometry
10 systems, the total area of the transparent plate **135** exposed by the aperture **145** is sized to enable the incident light beams **148a** to be moved or scanned across the surface of the substrate **30** to find a particular feature, such as a via or a deep narrow trench, or a suitably flat and/or transparent point at which to make a process endpoint measurement. For example, in a process
15 chamber **35** used for processing 300 mm substrates, the area of the aperture **145** should be preferably from about 200 to about 2000 mm² (0.3 to about 3 in²) and more preferably from about 400 to about 600 mm² (0.6 to about 0.9 in²).

20 In another embodiment, shown in Figures 4a and 4b, the mask **140** can also comprise a plurality of apertures **145** that are spaced apart from one another. For example, the mask can comprise an array of apertures **145** sized and arranged to have a total opening area that provides a sufficient intensity of light to pass through to operate the process monitoring
25 system **25**. The actual size, number or arrangement of apertures **145** depends upon the particular process chamber **35**, the substrate diameter, the process, and the type of process monitoring system **25**. In one embodiment which is particularly useful for interferometric optical systems, the mask **140** comprises apertures **145** having an opening dimension, such as a diameter or
30 a width of about 0.1 to about 50 mm, and a height of about 0.5 to about 500 nm. The array preferably consists of from about 3 to about 800 apertures **145**, and more preferably from about 7 to about 200 apertures **145**, as shown in Figure 4b. The apertures **145** are spaced apart from one another by a distance of about 0.25 to about 15 mm. Also, as shown in

Figure 3b, the array can comprise different sized apertures **145**, for example, first apertures **145a** in the central portion that have an average diameter of about 3.5 to 5 mm, and second apertures **145b** at its circumferential edge having a diameter of 2 to 3 mm.

5

It has been discovered that the mask **140** overlying the window **130** substantially reduces deposition of process residue on the transparent plate **135** of the window **130**. For example, the overlying mask **140** and window **130** has been found to reduce deposition of etchant residue in polysilicon etching processes down to about 3 to about 10 Å/hr, which is about 100 times lower than that occurring on conventional unprotected windows. In addition, the mask **140** protects the window **130** from erosion by highly chemically reactive process gases, and has been found to extend the lifetime of the window **130**. Also, the "footprint" (occupied area of clean room) of a process chamber **35** comprising a window **130** having a mask **140** according to the present invention is much smaller than that of other process chambers **35** having conventional clean-window systems.

The process chamber **35** and window **130** of the present invention allows use of process monitoring methods such as interferometry, ellipsometry, or plasma emission analysis. The reduced residue deposition on the process monitoring window **130** increases the signal to noise ratio of the process monitoring systems **25** to levels that provide accurate and reliable readings even after processing a large number of substrates **30**. The accuracy of these measurement techniques provides the necessary process control for the deposition and etching of thinner films on the substrate **30**, to provide faster and higher operating frequency integrated circuits. In addition, because the process chamber **35** does not have to be frequently opened to clean the surface of the window **130**, the process chamber efficiency and the substrate throughput is also enhanced.

Operation of a process chamber and process monitoring system **25** using a window **130** according to the present invention will now be described. As described above, the process monitoring system **25** can be an

interferometry or ellipsometry system that compares a property of the reflected light beam **148b**, such as its intensity and/or phase angle, to known or stored characteristic values to calculate the endpoint of the etching process. Preferably, the process monitoring system **25** comprises a

5 computer controller **155** that adjusts the process conditions in the process chamber **35**. Upon detection of the process endpoint, the computer controller **155** changes the first process conditions to second process conditions to change the rate of etching of the layer on the substrate **30** before the entire layer is etched through or to stop the etching process. For

10 example, the etch rate can be reduced by changing the composition of the process gas to remove aggressive etchant gases, the RF power coupled to the process gas can be lowered, or the substrate temperature can be lowered.

15 A suitable computer controller **155** comprises a computer program code product that operates the process chamber **35**, and comprises one or more central processor units (CPUs) interconnected to a memory system with peripheral control components, such as for example, a PENTIUM microprocessor, commercially available from Intel Corporation, Santa Clara,

20 California. The CPUs of the computer controller **155** can also comprise ASIC (application specific integrated circuits) that operate a particular component of the process chamber **35**. The interface between an operator and the computer controller **155** can comprise a CRT monitor and a light pen (not shown), or other devices, such as a keyboard, mouse or pointing

25 communication device.

The light source **150** comprises a monochromatic or polychromatic light source **150** that generates an incident light beam **148a** having an intensity sufficiently high to provide a reflected light beam **148b**

30 that is reflected from a layer on the substrate **30**, when the layer has a suitable thickness, with a measurable intensity. In one version, the light source **150** provides polychromatic light, such as a Hg-Cd lamp, which generates an emission spectrum of light in wavelengths from about 200 to about 600 nanometers. The polychromatic light source **150** can be filtered

to provide an incident light beam having selected frequencies, or particular emission spectra wavelengths can be used, or color filters (not show) can be placed in front of a light detector **160** for detecting the reflected light beam **148b** to filter out all undesirable wavelengths except the desired wavelength of light, prior to measuring the intensity of the reflected light beam **148b** entering the light detector **160**. The light source **150** can also comprise a monochromatic light source **150** that provides a selected wavelength of light, for example, a He-Ne or ND-YAG laser.

One or more convex focusing lenses **165** are used to focus the incident light beam **148a** from the light source **150** as a beam spot or collimated beam on the substrate surface and to focus the reflected light beam **148a** back on an active surface of the light detector **160**. The size or area of the beam spot should be sufficiently large to compensate for variations in surface topography of the substrate **30** to enable etching of high aspect ratio features having small openings, such as vias or deep narrow trenches. The area of the reflected light beam **148a** should be sufficiently large to activate a large portion of the active light detecting surface of the light detector **160**.

Optionally, a light beam positioner **170** is used to move the incident light beam **148a** across the substrate surface to locate a suitable portion of the layer being etched on which to "park" the beam spot to monitor etching process. The light beam positioner **170** comprises one or more primary mirrors **175** that rotate at small angles to deflect the incident light beam **148a** from the light source **150** onto different positions of the substrate surface, and to intercept the reflected light beam **148b** and focus it on the light detector **160**. In another embodiment, the light beam positioner **170** is used to scan the light beam in a raster pattern across the substrate surface during processing. In this version, the light beam positioner **170** comprises a scanning assembly consisting of a movable stage (not shown) upon which the light source **150**, focusing assembly, collecting lens, and detector are mounted. The movable stage can be moved through set

intervals by a drive mechanism, such as a stepper motor, move the beam spot across the substrate surface.

The light detector **160** comprises an electronic component
5 having a light sensitive surface, such as a photovoltaic cell, photodiode, or phototransistor, which provides a signal in response to the intensity of the reflected light beam **148b** that is incident on the light sensitive surface. The signal can be in the form of a change in the level of a current passing
10 through an electrical component or a change in a voltage applied across an electrical component. Preferably, the reflected light beam **148b** undergoes constructive and/or destructive interference which increases or decreases the intensity of the reflected light beam **148b** as the thickness of the film or trench on the substrate **30** increases or decreases, and the light detector **160**
15 provides an electrical output signal in relation to the measured intensity of the reflected light beam **148b**. The computer system receives the signal from the light detector **160**, compares the signal to a stored value or waveform, and changes process conditions in the process chamber **35** according to programmed guidelines in relation to the signal.

20 An example of a substrate processing method according to the present invention will now be described, with reference to an exemplary etching process, in which a polysilicon overlayer on a gate oxide (silicon dioxide) underlayer, is etched without etching or damaging the underlayer. Initially, a reflectance thickness measuring machine is used to accurately
25 determine the initial thickness of the layer to be etched on the substrate **30**, such as a model UV1050 available from KLA-TENCOR, Santa Clara, California. The actual layer thickness is useful to estimate the overall operation time of the etching process and/or to calculate the thickness of the layer that should be etched to provide a predetermined thickness of the layer
30 that remains on the substrate **30** after the etching process.

The substrate **30** is transferred by a robot arm (not shown) from a load-lock transfer chamber **180** through a slit valve and into the process zone **40** of the process chamber **35**. The substrate **30** is placed on

the support **45** where it is held by the electrostatic chuck **50**. Optionally, a heat transfer gas is supplied through holes **185** in the surface of the electrostatic chuck **50** to control the temperature of the substrate **30**.

Thereafter, the process conditions in the process chamber **35** are set to

- 5 process the particular layer on the substrate **30** and to form process gas byproducts, the process conditions comprising one or more of process gas composition and flow rates, power levels of gas energizers **60**, gas pressure, and substrate temperature. The process can also be performed in multiple stages, for example, each stage having different process conditions. For
- 10 example, in an etching process, one or more compositions of an energized process gas comprising etchant gas for etching the substrate **30** are provided in the process chamber **35**. Suitable etchant gases for etching layers on the substrate **30**, include for example, HCl, BCl₃, HBr, Br₂, Cl₂, CCl₄, SiCl₄, SF₆, F, NF₃, HF, CF₃, CF₄, CH₃F, CHF₃, C₂H₂F₂, C₂H₄F₆, C₂F₆, C₃F₈, C₄F₈, C₂HF₅,
- 15 C₄F₁₀, CF₂Cl₂, CFCl₃, O₂, N₂, He, and mixtures thereof. The process chamber **35** is typically maintained at a pressure ranging from about 0.1 to about 400 mTorr. The etchant gas composition is selected to provide high etch rates and/or high etching selectivity ratios for etching the overlayer relative to the underlayer. When multiple layers are being sequential etched, first, second,
- 20 third, etchant gas compositions can be sequentially introduced into the process chamber **35** to etch each particular layer.

- The process gas is energized and maintained at first process conditions suitable for etching the substrate **30**. Referring to Figure 1, an
- 25 energized process gas is provided in the process zone **40** by inductively and/or capacitively coupling energy into the process zone **40** using the gas energizer **60**, or by applying microwaves to an etchant gas in the remote zone **110** of the remote chamber **105**, as shown in Figure 2. By energized process gas, it is meant that the process gas is activated or energized so that
 - 30 one or more of dissociated species, non-dissociated species, ionic species, and/or neutral species are excited to higher energy states in which they are more chemically reactive. Preferably, the process gas is energized by applying an RF source current to the inductor antenna **100** encircling the process chamber **35** or by applying an RF bias voltage to the process

electrodes. The etchant gas ionizes in the applied electric field to form ions and neutrals that etch the layer on the substrate **30** to form volatile gaseous species that are exhausted from the process chamber **35**.

5 The process monitoring system **25** is used to precisely change process conditions, after a given thickness of the layer on the substrate **30** is processed. In etching processes, the process monitoring system **25** can be used to change the process gas composition to provide particular etching rates or etching selectivity ratios. For example, the process monitoring
10 system **25** can be used to stop the etching process after a first highly aggressive etching step, which provides high etch rates due to the presence of the fluorinated gas in the etchant gas, to determine the starting point for a second and less reactive etching step, which uses a process gas that is absent the fluorinated gas to etch the remaining dielectric layer at a slower
15 etch rate to obtain more controlled etching. The process monitoring system **25** is used to detect the time at which almost all of the silicon layer is etched so that the first process conditions can be changed to less aggressive or second process conditions, or vice versa, to obtain the desired change in etching rate, etching selectivity ratio, or a change in any other property of
20 the etching process, for example, higher/lower etching rates, or etching of underlying layers having a different composition.

 Generally, in the method of the present invention, the incident light beam **148a** is transmitted through the energized process gas in the
25 process zone **40** of the process chamber **35**, to be incident on the layers covering the substrate **30** while the layers are being etched. These experiments were conducted using a light source **150** consisting of a Hg-Cd lamp. A light beam from this light source **150** is directed through the window **130** to be incident on the substrate **30** at a near vertical angle, to
30 provide a beam spot having a size sufficiently large to cover one or more of the features being etched on the substrate **30**. It is preferred for the incident light beam **148a** to consist of substantially only non-polarized light, because polarized light is preferentially absorbed by deposition of a thin residue on the process window **130**.

When the thickness of the layer is sufficiently low (after etching for a period of time) a property of the reflected light beam **148b** that reflects off both the top and bottom surfaces of the layer on the substrate **30** is measured. Changes in the measured property, such as the intensity or phase of the reflected light beam, is recorded over time to form a measured waveform pattern. The measured waveform pattern is compared to a stored waveform pattern, and when the two signals are substantially the same, the endpoint of the etching process is reached. At that time, the first process conditions are changed to second process conditions in relation to the measurement of the property of the reflected light beam. For example, first process conditions are changed to second process conditions to stop the etching process, to change the rate of etching of the layer on the substrate **30**, or to change its etching selectivity ratio relative to the underlayer, before the entire layer is etched through.

The measured intensity of the reflected light beam **148b** can also be plotted over time to obtain a measured waveform pattern, and the measured waveform pattern is compared to a predetermined characteristic waveform pattern to determine an endpoint of the etching process that occurs when the two waveforms are the same or substantially identical to one another, as described in commonly assigned U.S. Patent Application No. 09/062,520, by Grimbergen et al, filed on April 17, 1998, which is incorporated herein by reference. In this method, a computer controller **155** plots the electrical output signal of the intensity of the reflected light beam **148b** over time to provide a waveform spectra having numerous waveform patterns corresponding to the varying intensity of the reflected light beam **148b**. The computer controller **155** calculates a real-time waveform spectra of light reflected from a thickness of a layer being processed on the substrate **30** and compares the waveform of the measured intensity to a stored characteristic waveform pattern and adjusts process conditions in the process chamber **35** when the two waveforms have substantially the same shape and form. The computer program determines the completion of a stage of processing of the layer when the measured waveform pattern comprises a repeatable waveform oscillation that occurs immediately before

a terminal peak or dip in a reflected waveform pattern, the terminal peak or dip corresponding to completion of processing of the layer. The computer program can also include program code to calculate in real time, the thickness of the layer being etched that remains on the substrate **30** and accordingly adjust the process conditions in the process chamber **35**. The computer program can also count the number of maxima and minima peaks in the intensity of the reflected light beam and, after a predetermined number of peaks are reached, alter process conditions in the process chamber **35**, according to programmed guidelines.

10

In another aspect of the present invention, an in-situ or dry cleaning process can be performed in conjunction with the process monitoring method of the present invention to enhance the operation of the process chamber **35**. In this method, a first layer on a substrate **30** is etched in a first stage of the etching process by a process gas comprising a composition of etchant gas that provides a high etching rate and a process chamber cleaning gas that removes the residue deposits and process gas byproducts as they are formed on the walls of the process chamber **35**. Because the cleaning gas is an extremely aggressive fluorine containing gas which will quickly etch through a thin underlying gate oxide layer, the process monitoring system **25** is used to detect the process endpoint and change the composition of the process gas to remove the cleaning gas immediately prior to etching through the first layer. The cleaning gas in the first stage of the process cleans the process chamber **35** without requiring stopping etching in between processing of batches of substrates **30** to perform wet cleaning processes. In a preferred embodiment, the etchant gas comprises one or more of Cl_2 , N_2 , O_2 , HBr , or He-O_2 ; and the cleaning gas comprises inorganic non-hydrocarbon containing fluorinated gas such as one or more of NF_3 , CF_4 , or SF_6 . Preferably, the volumetric flow ratio of cleaning gas to etchant gas is selected to remove substantially all residue deposits and process gas byproducts from process chamber surfaces upon completion of the first stage. More preferably, the volumetric flow ratio of cleaning gas to etchant gas is selected to remove substantially all residue deposits and process gas byproducts formed during processing of at least 2000 substrates

30 in the process chamber 35, without performing a separate cleaning step for cleaning the process chamber 35. A suitable volumetric flow ratio of cleaning gas to etchant gas is from about 1:20 to about 1:1, and more preferably from about 1:10 to about 2:3, and most preferably about 2:3. It has been discovered that at these volumetric flow ratios substantially all the etchant residue on the process chamber surfaces is removed without eroding the process chamber surfaces. In addition, it has been unexpectedly discovered that the process chamber surfaces are cleaned and conditioned by the etchant and cleaning gas combination step, without requiring a separate process chamber conditioning or seasoning step. Suitable cleaning gas compositions are provided in aforementioned U.S. Patent Application No. 09/062,520.

EXAMPLES

The following examples illustrate use of a process chamber 35 having a window 130 and mask 140 according to the present invention. In these examples, a series of 200 mm silicon substrates 30 having a 2500 Å polysilicon layer, a 45 Å silicon dioxide layer, and a 2000 Å patterned resist layer, were etched. A multi-stage process was used for etching the polysilicon layer on a substrate 30. In a first or main etching stage, an energized process gas comprising 50 sccm CF₄ and 40 sccm SF₆ is provided in the process chamber 35 to etch through most of the thickness of the polysilicon layer exposed through openings in the resist layer. The process gas is energized by applying a source power of 750 watts to the inductor antenna 100, and a bias power of 90 watts to the process electrodes 45, 55. The process chamber pressure is maintained from about 2 to about 3 mTorr. After the process endpoint is detected using a process monitoring system 25, the main etch stage was stopped and remaining polysilicon removed in a second or over-etch stage substantially without damaging the underlying silicon dioxide layer. In the overetch stage, a second energized process gas comprising 60 sccm of SF₆ is introduced in the process chamber 35, and energized by a source power of 600 watts and a bias power of 1

watt. The process chamber **35** is maintained at a pressure of about 10 mTorr.

The process was performed in a process chamber **35** having a
5 window **130** comprising masks **140** of varied thicknesses and having
apertures **145** of varying number, diameter, and aspect ratios to determine
their effectiveness in reducing accumulation of process residue on the
transparent plate **135**. In general, the mask **140** comprised an aluminum
oxide disc having a raised central portion **153** surrounded by a thin annular
10 lip **154** as shown in Figure 4b. The mask **140** was positioned about 0.038"
from the transparent plate **135**, and small slides (not shown) of an etch
resistant material such as sapphire or Kapton® were positioned between the
mask **140** and transparent plate **135** to shield a portion of the transparent
plate **135** exposed through each aperture **145**. The total time the process
15 chamber **35** was in operation was recorded and after a specified times the
window **130** was removed and the thickness of process residue deposited on
and/or the amount of material removed from the transparent plate **135** was
measured using a stylus step height measuring device such as a DekTak, or
an Alpha-step. The transmission of light through the transparent plate **135**
20 was also measured using a light source of known intensity and a light
detector capable of accurately measuring the intensity of the transmitted
light.

Example 1:

25

In a first example, the mask **140** had a raised central portion
153 19 mm (0.75") thick, and comprised a hexagonal pattern of 19
apertures, each 3.8 mm (0.15") wide and each having an aspect ratio of 5:1.
This example demonstrates that an array of apertures **145** having a small
30 diameter and a large aspect ratio reduce deposition of process residue on the
transparent plate **135** of the window **130**. After etching in the chamber for
80 minutes, the window **130** was disassembled, the sapphire slide removed,
and the transparent plate **135** scanned using a stylus step height
measurement instrument to determine the accumulation of process residue

and the etching of the transparent plate **135**. Because the high aspect ratio of the small apertures **145** excluded all the residue forming plasma species from reaching the transparent plate **135**, there was no discernable etching of the transparent plate **135**. Moreover, the thickness of process residue on the transparent plate **135** was below the limit that could be measured, i.e., less than 600 Å. The change in transmission of light through the transparent plate **135** was also found to be below detectable limits, i.e., less than 1 %.

Example 2:

10

In this example, the mask **140** comprised a raised central portion **153** 0.75" thick and circular apertures **145** having varying diameters from 0.1" to 1". After the process chamber **35** was operated for 80 minutes, the mask **140** was found to significantly reduce deposition on the transparent plate **135** as compared to conventional windows. The window **130** was replaced, uncleaned, and examined again after an additional 18 and 25 hours of operation. The accumulation of residue deposits, and etching of the transparent plate **135** for the various sized apertures **145** after 25 hours of operation is summarized in Table I.

20

TABLE I

25

HOLE SIZE (inches)	ASPECT RATIO	CENTER THICKNESS (angstroms)	EDGE ETCH (angstroms)	PROJECTED TRANSMISSION OF 245 NM AT 150 HOURS
1"	0.75	4000 to 5000	-3000 to -6000 Å at 5mm	High at edge; moderate in center
0.5"	1.5	0	-2500 Å	High
0.25"	3	550 to 650	-250 Å at 0.5mm	Moderate
0.2"	3.75	410 to 500	None	Moderate to High
0.15"	5	170 to 200	None	High
0.1"	7.5	70 to 100	None	High

30

Referring to the graph of Figure 5 it is seen that as the diameter of the aperture 145 becomes smaller and the aspect ratio increases, the flow of neutral plasma species flux that contribute to deposition of the process residue deposits into the aperture 145 is gradually reduced and can be
5 entirely excluded from reaching the transparent plate 135. The net deposition of process residue on the transparent plate 135 initially increases as the diameter of the apertures 145 are reduced from 0.5" to 0.25", and thereafter decreases as the aperture 145 continues to become smaller. In contrast, as aperture size increases above 0.5" and the aspect ratio is
10 reduced from 2:1 to 0.75:1, deposition controls at the center of the aperture 145, while etching dominates near the sidewall or edge of the aperture 145. In contrast, for apertures 145 having aspect ratios of from about 1 to about 2, there is negative net deposition rate across substantially the entire width of the aperture, arising from allowing entry of substantially only energetic
15 plasma species into the aperture 145.

Magnetic Field Confinement

In another embodiment of the present invention, as illustrate is
20 Figure 6a, the process chamber 35 comprises a magnetic field source 195 that is adapted to provide or serve as means for maintaining a magnetic flux near or across the window 130. When a substrate 30 held on the support 45 is processed by the energized process gas, the magnetic flux extending across a portion of the window 130 reduces the deposition of the process
25 residues on the transparent plate 135 of the window. The magnetic field source 195 comprises at least one permanent magnet 200 or electromagnet (not shown) that is positioned adjacent to the window 130 to couple magnetic energy or flux across at least a portion of the surface of the window 130. Preferably, the magnetic field lines are generally confined to
30 the space around the window 130, and penetrate only a shallow depth or not at all into the process chamber 35.

A preferred magnetic field source 195 comprises a permanent magnet 200 arranged about the window to provide a magnetic field

component that extends across a portion of the transparent plate **135** and in the plane of the window **130**. Preferably, the magnetic field source **195** provides a localized magnetic flux across the window **130** that has a higher density across the window than their density at other portions of the process chamber **35**, and that terminates at the edges of the window **130**.

The magnetic flux across the window **130** comprises magnetic field components that prevent charged process gas species from reaching the transparent plate **135**. For example, when the magnetic field lines or magnetic flux has a directional vector that is parallel to the plane of the window **130**, the field lines serve to confine charged plasma ions and electrons of the energized process gas to a circular path that is at a some fixed average distance away from the transparent plate **135** and thereby prevents deposition of process residues on the plate **135**. For example, a magnetic flux that extends across a portion of the window **130** and along a plane parallel to the window causes charged ions and electrons entering the region of the magnetic flux to rotate in a circular motion in this region. The magnetic field strength should be sufficiently high to confine the charged ions and electrons to the region of the magnetic field substantially without allowing the charged species to exit from this region. Generally, a suitable magnetic field strength is from about 10 to about 10,000 Gauss, and more preferably from about 50 to about 2000 Gauss.

In one embodiment, shown in Figures 6b through 6d, the magnetic field source **195** comprises a plurality of magnetic poles **205** disposed about a perimeter of the window **130**. The magnetic poles **205** around the perimeter of the window **130** comprise opposing magnetic polarities that are in facing relationship to one another. For example, as shown in Figure 6b, the magnetic field source **195** can comprise at least a pair of north and south poles **205a,b** that face one another. Preferably, the magnetic field source **195** comprises a magnetic yoke **210** (by which it is meant a ferromagnetic yoke of a permanent magnet or an electromagnet) having an aperture **215** therein. The magnetic yoke **210** provides a symmetrical magnetic field across the aperture **215**. Figure 6b shows an

exemplary magnetic yoke **210** comprising at least a pair of radially extending poles **205a,b** that face one another and have opposing magnetic polarity. Alternatively, as shown in Figure 6d the magnetic yoke **210** can comprise a plurality of yokes of magnetic material that are arranged to provide a plurality of radially opposing magnetic poles **205** facing one another across the aperture **215** to provide a magnetic flux across the surface of the window **130**.

The aperture **215** in the annular shaped or circumferentially disposed magnetic yoke **210** is sized to allow light to pass through the window **130**. The facing magnetic poles **205a,b** apply a magnetic field generally straight across the aperture **215** in the magnetic yoke **210**. The aperture **215** is sized sufficiently large to allow a sufficient intensity of light to pass through to operate the process monitoring system **25**. The total cross-sectional area of the aperture **215** is sufficiently large to allow a sufficiently large amount of light to ingress and egress from the process chamber **35** through the aperture **215**. The aperture can be cylindrical, triangulated, or rectangular in shape, of which a cylinder provides good axial symmetry for the magnetic field source and smooth internal surfaces.

Electrical Field Energizing

In another version, the process chamber **35** comprises a window **130** in a wall or the ceiling **55** of the process chamber **35** and an electrical field source **220** that couples electrical energy to the window **130**. The electrical energy coupled to the window **130** reduces the accumulation of the process residues on the window **130** by causing energized process gas ions to energetically bombard the window **130** and remove process residues deposited on the window. The electric field source **220** comprises an electrode **225** adjacent to the window. For example, as shown in Figure 7, the electrical field source **220** comprises an electrode **225** disposed adjacent to and behind the window **130** to induce a charge in the window and to generate an electric field perpendicular to the plane of the window **130** which causes energetic plasma ions and species in the process chamber

35 accelerate toward and impinge upon on the window **130** to sputter-etch and remove the process residue deposits formed on the window.

In another version, shown in Figure 8a, the electric field source
5 **220** comprises an electrode **225** having one or more apertures **230** therein, disposed between the transparent plate **135** and the light source **150** to provide an electric field that is perpendicular to the plane of the window **130**. The electrical field causes energetic plasma ions and species in the process chamber **35** accelerate toward the window **130**, pass through the aperture
10 **230**, and impinge upon on the transparent plate **135** to sputter-etch and remove the process residue deposits. Preferably, the total cross-sectional area of the apertures **230** is sufficiently large to allow a sufficiently large amount of light flux to ingress and egress from the process chamber **35** through the aperture to operate the process monitoring system.

15
Additionally, eddy current reducing slots **232** are also sized, shaped, and disposed to reduce eddy currents induced in the electrode **225** by preventing a continuous pathway of current from being forming in the electrode. Eddy currents occur due to the electrical energy coupled from
20 other process components, such as the inductor antenna **100**. The slots **232** reduce or eliminate the eddy currents by breaking up the circular pathway of the current in the electrode **225**. For example, as shown in Figure 8b, the electrode **225** can comprise a disc **235** having at least one radially extending cutout **240** that is in the pathway of the eddy current
25 induced in the electrode **225**. Alternatively, as shown in Figures 8c and 8d, the electrode **225** comprises a series of radial wedge-shaped cuts **242** or an array of circular holes **243** spaced apart from one another.

As with the magnetic field source **195**, the electrical field
30 source **220** is adapted to provide an electrical field or flux that extends across a portion of or substantially the entire surface of the window **130**, and that terminates at or near the edges of the window **130**. More preferably, the electrode **225** is sized sufficiently large to provide an electric field that covers the entire area of the transparent plate **135** of the window

130 and is shaped and sized similar to the shape of the window 130. A voltage source 245 electrically biases the electrode 225 with one of a D.C. voltage, an A.C. voltage, or an RF voltage. Alternatively, as shown in Figure 8a, the electrode 225 can be electrically biased by a tap 250 connecting a selected coil of the inductor antenna 100 to the electrode 225. Thus the coil power supply 104 provides power to both the window electrode 225 and the inductor antenna 100. Preferably, coil power supply 104 biases the electrode 225 with a voltage of from about 10 to about 10,000 volts, and more preferably from about 20 to about 4000 volts.

The mask 140 can also be used in combination with the magnetic and electrical field confinement methods. In this method, the mask 140 having the aperture 145 is aligned over the aperture 215 in the magnetic yoke 210 or over the aperture 230 in the electrode 225, to align the aperture 145 to the apertures 210 or 230. The aperture 145 of the mask 140 is shaped and sized to limit or reduce access of the energized process gas into the aperture 215 of the magnetic yoke 210 to prevent deposition of process gas byproducts and other deposits on the underlying transparent plate 135. Alternatively, the aperture 145 is sized and shaped to screen out low energy plasma species and only allow highly energetic and directional plasma species into the aperture 145. The highly energetic and directional species impinge upon sidewalls of the aperture 145 and upon the surface of the transparent plate 135 to sputter-etch and remove process gas deposits that are formed thereon.

The substrate 20 and process of the present invention allows accurate and reliable monitoring of the process being conducted in the process chamber 35 without excessive deposition of residues and deposits on the window 130 for the process monitoring system 25. The improved window 130 structure further reduces flaking of deposits from window components and thereby increases substrate yields. The window 130 is also much less susceptible to erosive damage from the plasma in the process chamber 35 than conventional windows 130. By reducing the need to often replace the window 130, the cost of operating the process chamber 35 and

the cost per substrate 30 are also significantly reduced. Furthermore, the masked window 130 configuration allows use of the process chamber 35 over an extended period of time without stopping processing to wet clean the process chamber walls and components including the window 130, thereby increasing etching throughput and further reducing costs per substrate 30. The magnetic and electrical field confinement methods, can operate separately or in combination with the masking method, to reduce to entirely eliminate process residue deposition on the window.

10 The etching and endpoint detection method of the present invention significantly improve substrate yields by reducing etching or other damage of the thin gate oxide underlayer, during etching of an overlying polysilicon layer. In particular, the polysilicon etching process is stopped without etching through an ultra-thin gate oxide layer having a thickness of
15 25 to 65 angstroms, which is only a few layers of atoms of silicon dioxide, and which is 4 to 5 times thinner than prior art gate oxide layers. The etching method also minimizes the damage that a high density RF bias plasma can cause by the formation of damaging electrical currents that are coupled through the thin gate oxide layer into the silicon wafer. Also, by
20 stopping the etching process before the thin gate oxide layer is damaged by the aggressive etching process step, the present process provides higher yields and better quality of integrated circuits.

 Furthermore, the combination etching/cleaning process of the
25 present invention has been found to uniformly etch substrates 30 while simultaneously removing etchant residues deposited on the process chamber 35 during the etching process, irrespective of the thickness or chemical stoichiometry of the etchant residue layers. Prior art etching processes required cleaning and conditioning of the process chamber 35 after
30 processing of only 200 to 300 wafers, because of the variation in etching rates and etching selectivity ratio and the higher particle contamination levels that resulted from etchant residue deposits on the process chamber surfaces, after processing this number of wafers. Also, prior art cleaning processes, particularly those performed by an operator, often fail to uniformly clean and

remove the etchant residue deposits formed on process chamber surfaces, and such build-up of etchant deposits resulted in flaking off and contamination of the substrate 30.

5 The present invention is described with reference to certain preferred versions thereof; however, other versions are possible. For example, the treatment and cleaning process of the present invention can be used for treating process chambers 35 for other applications, as would be apparent to one of ordinary skill. For example, the process can be applied,
10 as would be apparent to one of ordinary skill in the art, to treat sputtering chambers, ion implantation chambers, or deposition chambers, or in combination with other cleaning processes. Therefore, the spirit and scope of the appended claims should not be limited to the description of the preferred versions contained herein.

15

What is claimed is:

1. A substrate processing chamber comprising:
 - (a) a support;
 - 5 (b) a gas distributor;
 - (c) a gas energizer;
 - (d) a wall comprising a radiation transmitting portion;
 - (e) a mask overlying the radiation transmitting portion, the mask having an aperture; and
 - 10 (e) an exhaust,whereby a substrate held on the support may be processed by process gas distributed by the gas distributor, energized by the gas energizer, and exhausted by the exhaust, and whereby the mask is adapted to reduce deposition of process residue on the radiation transmitting portion and
15 whereby radiation may be transmitted through the aperture of the mask and the radiation transmitting portion.
2. A substrate processing chamber according to claim 1 wherein the mask comprises an aperture having an aspect ratio that is
20 sufficiently large to reduce access of process gas to the radiation transmitting portion.
3. A substrate processing chamber according to claim 1 wherein the mask comprises an aperture having an aspect ratio of from
25 about 1:1 to about 12:1.
4. A substrate processing chamber according to claim 1 wherein the mask comprises an aperture having an aspect ratio that is sufficiently small to allow ions of the energized process gas to enter the
30 aperture and etch away the process residue formed on a sidewall of the aperture and on the radiation transmitting portion.

5. A substrate processing chamber according to claim 1 wherein the mask comprises an aperture having an aspect ratio of from about 0.25:1 to about 3:1.

5 6. A substrate processing chamber according to claim 1 wherein the mask comprises an aperture having a diameter or width of from about 0.1 to about 50 mm, and a height of about 0.5 to about 500 mm.

10 7. A substrate processing chamber according to claim 1 wherein the mask comprises an array of hexagonal apertures.

15 8. A substrate processing chamber according to claim 1 wherein the mask comprises a material that is resistant to erosion by the process gas.

9. A substrate processing chamber according to claim 8 wherein the mask comprises one or more of Al_2O_3 , SiO_2 , AlN , BN , Si , SiC , Si_3N_4 , TiO_2 , or ZrO_2 .

20 10. A substrate processing chamber according to claim 1 further comprising an electrical field source that is adapted to couple electrical energy to the wall to reduce deposition of the process residues on the wall.

25 11. A substrate processing chamber according to claim 1 further comprising a magnetic field source adapted to provide a magnetic flux across the wall to reduce deposition of process residues on the wall.

30

12. A substrate processing chamber comprising:

- (a) a support having a receiving surface capable of supporting a substrate;
- (b) a gas distributor capable of providing process gas in the chamber and a gas energizer that is capable of coupling energy to the process gas;
- (c) a radiation transmitting portion that allows radiation to be transmitted therethrough to monitor processing of the substrate;
- (d) means extending into the interior of the chamber for reducing deposition of process residue from process gas on the radiation transmitting portion; and
- (e) an exhaust capable of exhausting process gas from the chamber.

13. A substrate processing chamber according to claim 12 wherein the means for reducing deposition of process residue on the radiation transmitting portion comprises means for controlling access of energized process gas species to the radiation transmitting portion.

14. A substrate processing chamber according to claim 12 wherein the means for reducing deposition of process residue on the radiation transmitting portion comprises a mask capable of masking the radiation transmitting portion from the energized process gas.

15. A substrate processing chamber according to claim 12 wherein the means for reducing deposition of process residue on the radiation transmitting portion comprises an overlying mask having apertures with an aspect ratio of from about 1:1 to about 12:1.

16. A substrate processing chamber according to claim 15 wherein the mask comprises an aperture having an aspect ratio of from about 0.25:1 to about 3:1.

17. A substrate processing chamber according to claim 12 further comprising an electrical field source that couples electrical energy to the radiation transmitting portion to further reduce deposition of process residues on the radiation transmitting portion.

5

18. A substrate processing chamber according to claim 12 further comprising a magnetic field source adapted to provide a magnetic flux across the radiation transmitting portion to further reduce the deposition of process residues on the radiation transmitting portion.

10

19. A substrate processing chamber comprising:

(a) a support;

(b) a gas distributor;

(c) a gas energizer;

15 (d) a radiation transmitting portion comprising a mask with a plurality of apertures; and

(e) an exhaust;

whereby a substrate held on the support may be processed by process gas distributed by the gas distributor, energized by the gas energizer, and
20 exhausted by the exhaust, and whereby radiation may be transmitted through the radiation transmitting portion.

20. A substrate processing chamber according to claim 19 wherein the apertures have aspect ratios that are sufficiently large to reduce
25 access of process gas to the radiation transmitting portion.

30

21. A substrate processing comprising:

- (a) a support;
- (b) a gas distributor;
- (c) a gas energizer;
- 5 (d) a wall comprising an aperture, the aperture having an aspect ratio selected to reduce deposition of process residue;
- (e) an exhaust; and
- (f) a process monitoring system,

whereby a substrate held on the support may be processed by process
10 gas distributed by the gas distributor, energized by the gas energizer, and exhausted by the exhaust, and whereby radiation may be transmitted through the aperture to the process monitoring system.

22. A substrate processing chamber according to claim 21
15 wherein the wall comprises a radiation transmitting portion.

23. A substrate processing chamber according to claim 21
wherein the aspect ratio is sufficiently large to reduce access of process gas
to the radiation transmitting portion.

20 24. A substrate processing chamber according to claim 21
wherein the wall comprises a mask.

25 25. A substrate processing chamber according to claim 24
wherein the mask blocks an otherwise exposed portion of a radiation
transmitting portion.

26. A window capable of being mounted on a process
chamber, the window comprising:
30 a radiation transmitting portion and
an overlying mask with an aperture,
whereby the mask is adapted to reduce deposition of process residue
on the window and whereby radiation may be transmitted through the
window when a substrate is processed in the process chamber.

27. A window according to claim 26 wherein the mask comprises an aperture having an aspect ratio that is sufficiently large to reduce access of process gas to the radiation transmitting portion.

5 28. A window according to claim 26 wherein the mask comprises an aperture having an aspect ratio of from about 1:1 to about 12:1.

10 29. A window according to claim 26 wherein the mask comprises an aperture having an aspect ratio that is sufficiently small to allow ions of an energized process gas to enter the aperture and etch away the process residues formed on a sidewall of the aperture and on window.

15 30. A window according to claim 26 wherein the mask comprises an aperture having an aspect ratio of from about 0.25:1 to about 3:1.

20 31. A window according to claim 26 wherein the mask comprises an aperture having a diameter or width of from about 0.1 to about 50 mm, and a height of about 0.5 to about 500 mm.

32. A window according to claim 26 wherein the mask comprises a material that is resistant to erosion by a process gas.

25 33. A window according to claim 26 wherein the mask comprises a plurality of apertures.

30 34. A window according to claim 26 wherein the mask comprises an array of hexagonal apertures.

35. A window according to claim 26 wherein the mask comprises one or more of Al_2O_3 , SiO_2 , AlN , BN , Si , SiC , Si_3N_4 , TiO_2 , or ZrO_2 .

36. A window according to claim 26 wherein the radiation transmitting portion is absent a heating element for heating the radiation transmitting portion.

5 37. A window according to claim 26 further comprising an electrical field source that is adapted to couple electrical energy to the radiation transmitting portion to reduce deposition of the process residues on the radiation transmitting portion.

10 38. A window according to claim 26 further comprising a magnetic field source adapted to provide a magnetic flux across the radiation transmitting portion to reduce deposition of process residues on the radiation transmitting portion.

15 39. A method of processing a substrate in a process chamber, the method comprising the steps of:

- (a) placing the substrate in the process chamber;
- (b) maintaining first process conditions in the process chamber to process the substrate, the first process conditions including
- 20 providing an energized process gas in the process chamber;
- (c) masking a radiation transmitting portion in a wall of the process chamber to reduce deposition of process residue on the radiation transmitting portion and measuring a property of radiation transmitted through the radiation transmitting portion; and
- 25 (d) changing the first process conditions to second process conditions in relation to the measured property of the transmitted radiation.

40. A method according to claim 39 further comprising the

30 step of directing an incident light beam through the radiation transmitting portion to be incident on the substrate and measuring a property of a reflected light beam that is reflected from the substrate and transmitted through the radiation transmitting portion.

41. A method according to claim 39 wherein the first process conditions comprise process conditions suitable for etching the substrate, and the second process conditions comprise process conditions suitable for stopping the etching process or changing a rate of etching of the substrate.

42. A method of processing a substrate in a process chamber, the method comprising the steps of:

- (a) placing the substrate in the process chamber;
- (b) maintaining process conditions in the process chamber to process the substrate, the process conditions including providing an energized process gas in the process chamber; and
- (c) maintaining a magnetic flux across a portion of a wall of the process chamber.

43. A method according to claim 42 wherein the portion of the wall comprises a radiation transmitting portion.

44. A method according to claim 42 wherein step (c) comprises the step of maintaining a magnetic flux that is sufficiently high to reduce the deposition of process residue on the portion of the wall.

45. A method according to claim 42 wherein step (c) comprises the step of maintaining a magnetic flux having a magnetic field component that is substantially parallel to a plane of the portion of the wall.

46. A method according to claim 42 wherein step (c) comprises the step of maintaining a magnetic flux that is localized across a radiation transmitting portion of the wall, and comprises a higher magnetic flux across the radiation transmitting portion than across other portions of the chamber.

47. A method according to claim 42 wherein step (c) comprises the step of maintaining a plurality of magnetic poles about a perimeter of a radiation transmitting portion of the wall.

5 48. A method according to claim 42 wherein step (c) comprises the step of maintaining opposing magnetic poles that face one another around a perimeter of a radiation transmitting portion of the wall.

10 49. A method according to claim 42 wherein step (c) comprises the step of maintaining a magnetic flux having a magnetic field component that is substantially parallel to a plane of a radiation transmitting portion of the wall.

15 50. A method according to claim 42 wherein step (c) comprises the step of maintaining a magnetic flux that extends across a surface of a radiation transmitting portion of the wall.

20 51. A method according to claim 42 further comprising the step of providing a mask covering a radiation transmitting portion of the wall, the mask comprising an aperture that allows radiation to pass through.

52. A method of processing a substrate in a process chamber, the method comprising the steps of:

- 25 (a) placing the substrate in the process chamber;
- (b) maintaining first process conditions in the process chamber to process the substrate, the first process conditions including providing an energized process gas in the process chamber;
- 30 (c) maintaining a magnetic flux across at least a portion of a radiation transmitting portion in a wall of the process chamber;
- (d) measuring a property of radiation transmitted through the radiation transmitting portion; and
- (e) changing the first process conditions to second process conditions in relation to the measured property of the transmitted radiation.

53. A method of processing a substrate in a process chamber, the method comprising the steps of:

- (a) placing the substrate in the process chamber;
- (b) maintaining process conditions in the process chamber to process the substrate, the process conditions including providing an energized process gas in the process chamber; and
- (c) electrically biasing a portion of a wall of the process chamber.

54. A method according to claim 53 wherein the portion of the wall comprises a radiation transmitting portion.

55. A method according to claim 53 wherein step (c) comprises the step of electrically biasing the portion of the wall by a voltage that is sufficiently high to reduce deposition of process residue on the portion of the wall.

56. A method according to claim 53 wherein step (c) comprises the step of maintaining an electrode or coil adjacent to the portion of the wall, the electrode or coil being sized to provide an electrical flux across a surface of the portion of the wall.

57. A method according to claim 56 comprising the step of powering the electrode or coil with D.C., A.C., or R.F. energy.

58. A method according to claim 53 further comprising the steps of measuring a property of radiation transmitted through a radiation transmitting portion, and changing the process conditions in relation to the measured property of the transmitted radiation.

ABSTRACT

A process chamber **35** for processing a substrate **30** and monitoring the process conducted on the substrate **30**, comprises a support
5 **45**, a gas distributor, and an exhaust **85**. The process chamber **35** has a wall which may comprise a window or radiation transmitting portion **130** that allows light to be transmitted therethrough. Residue deposits onto the window **130** during processing of the substrate **30** may be reduced. In one
10 version, the window **130** comprises a transparent plate **135** covered by an overlying mask **140** that has at least one aperture **145** extending through the mask **140** so that light can be transmitted through the aperture **145** and the transparent plate **135**.

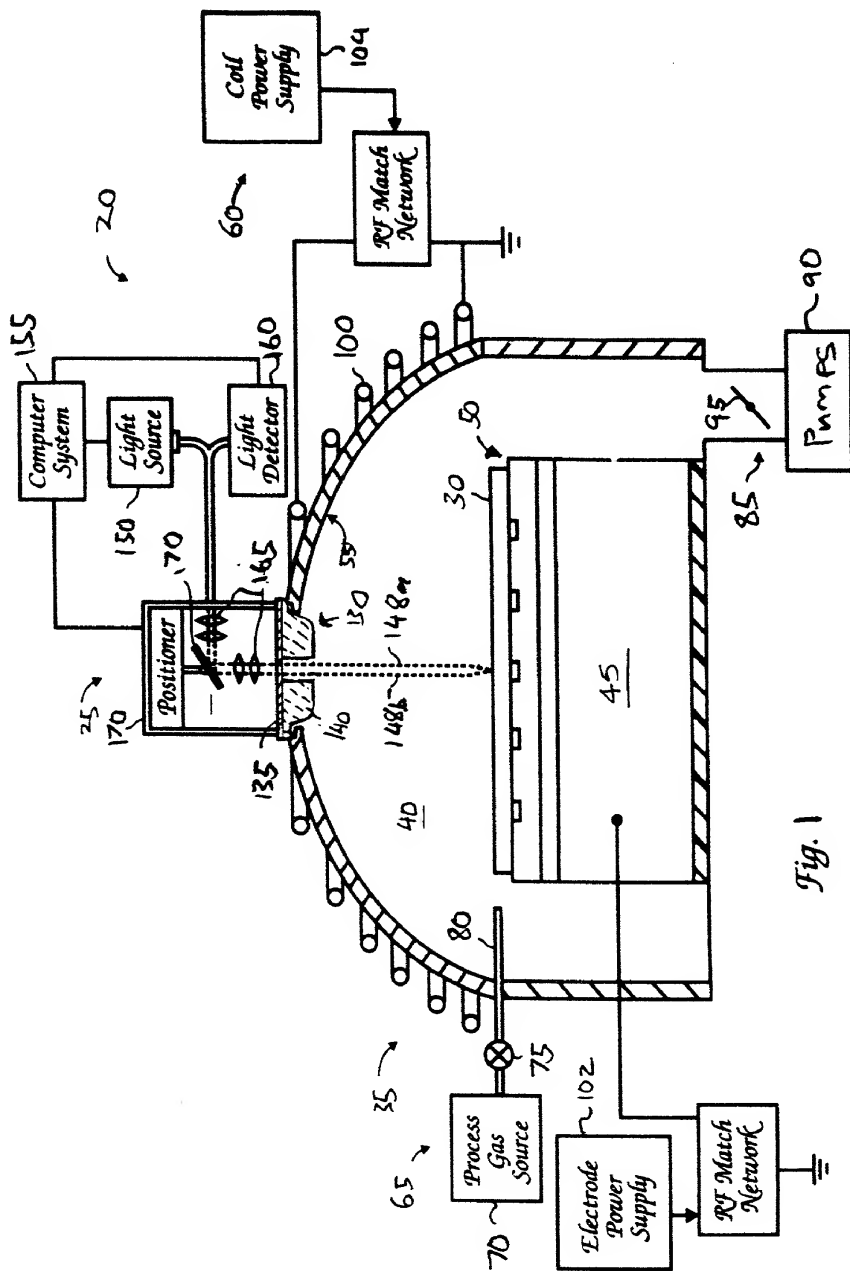
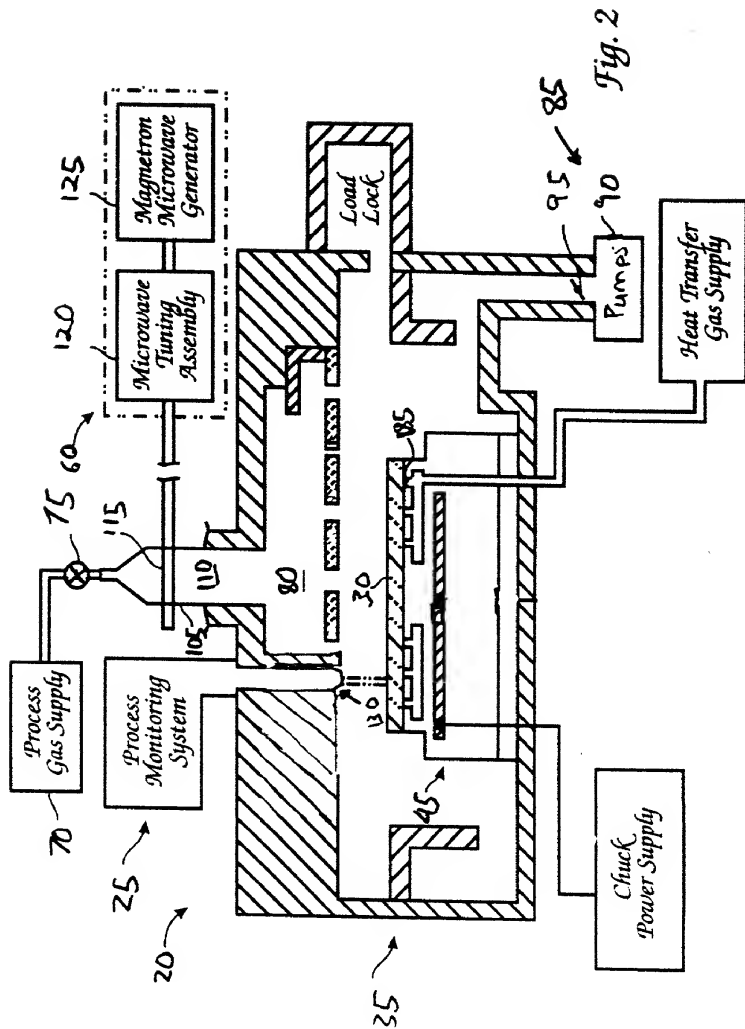
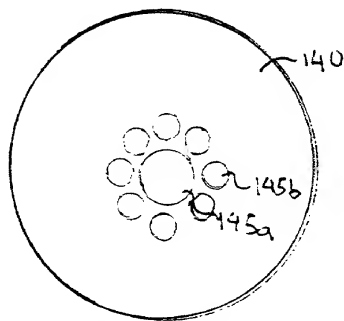
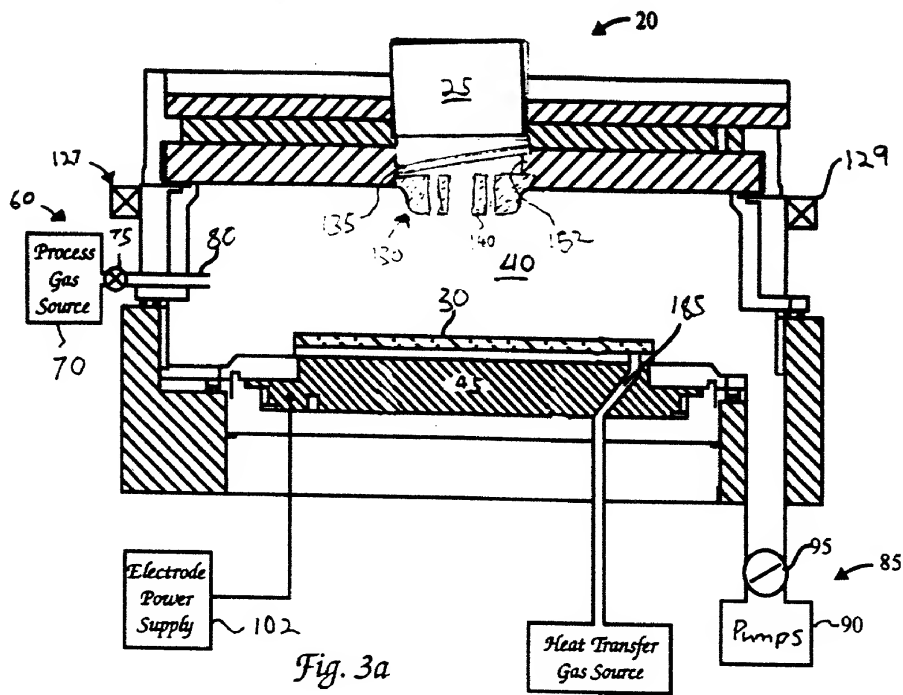


Fig. 1





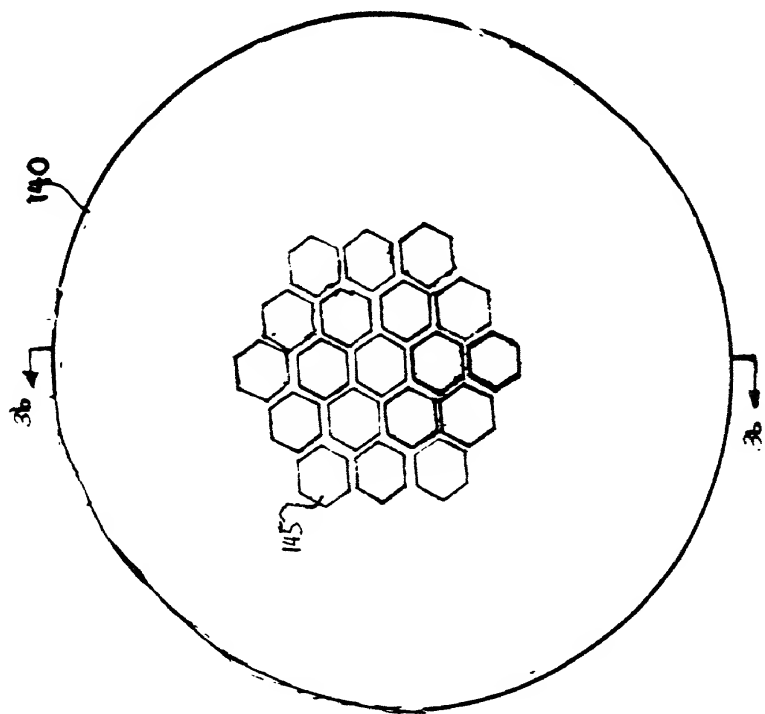


Fig 4a

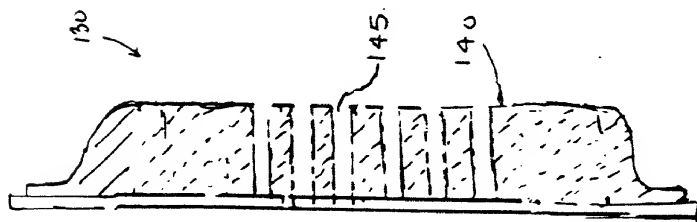


Fig 4b

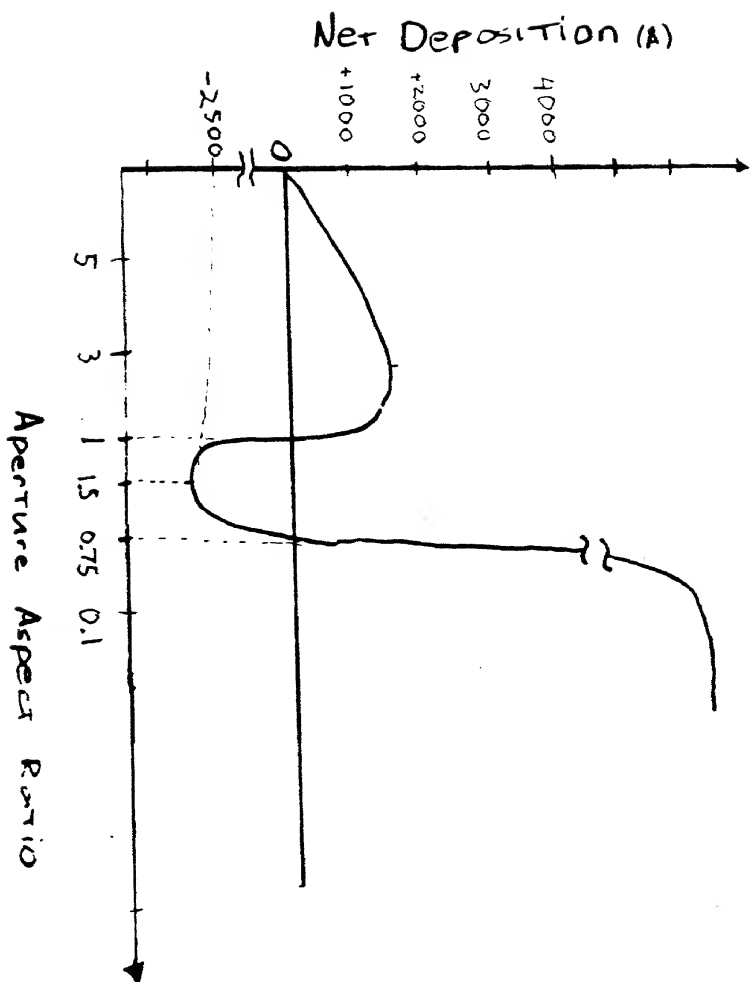


Fig 5

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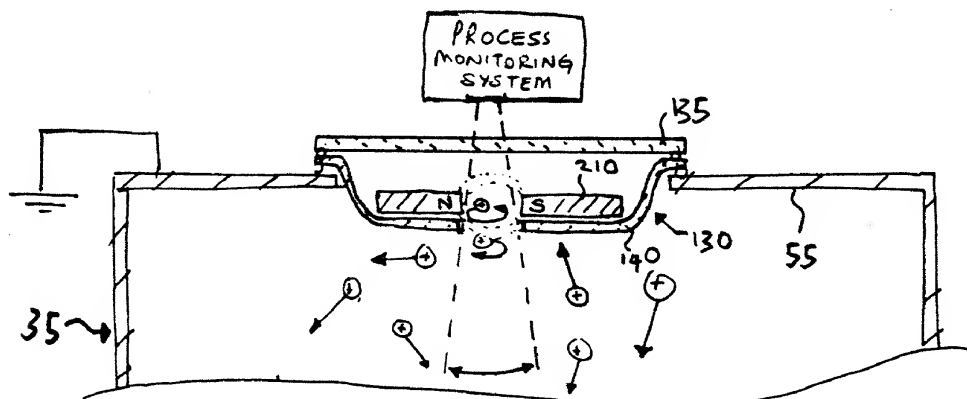


Fig. 6a

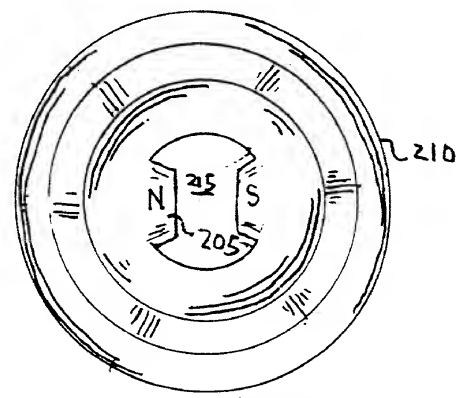


Fig. 6b

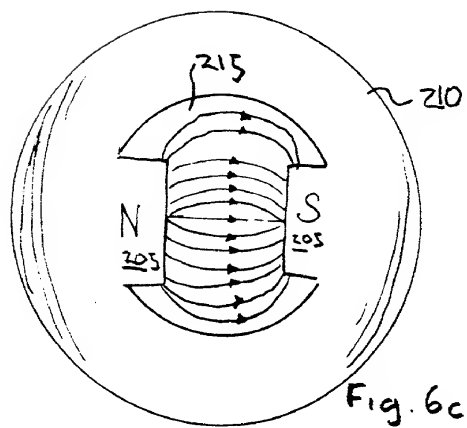


Fig. 6c

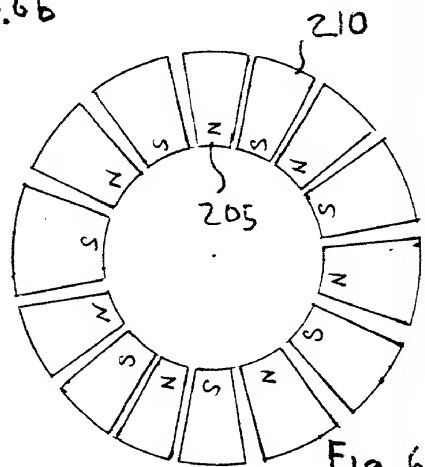
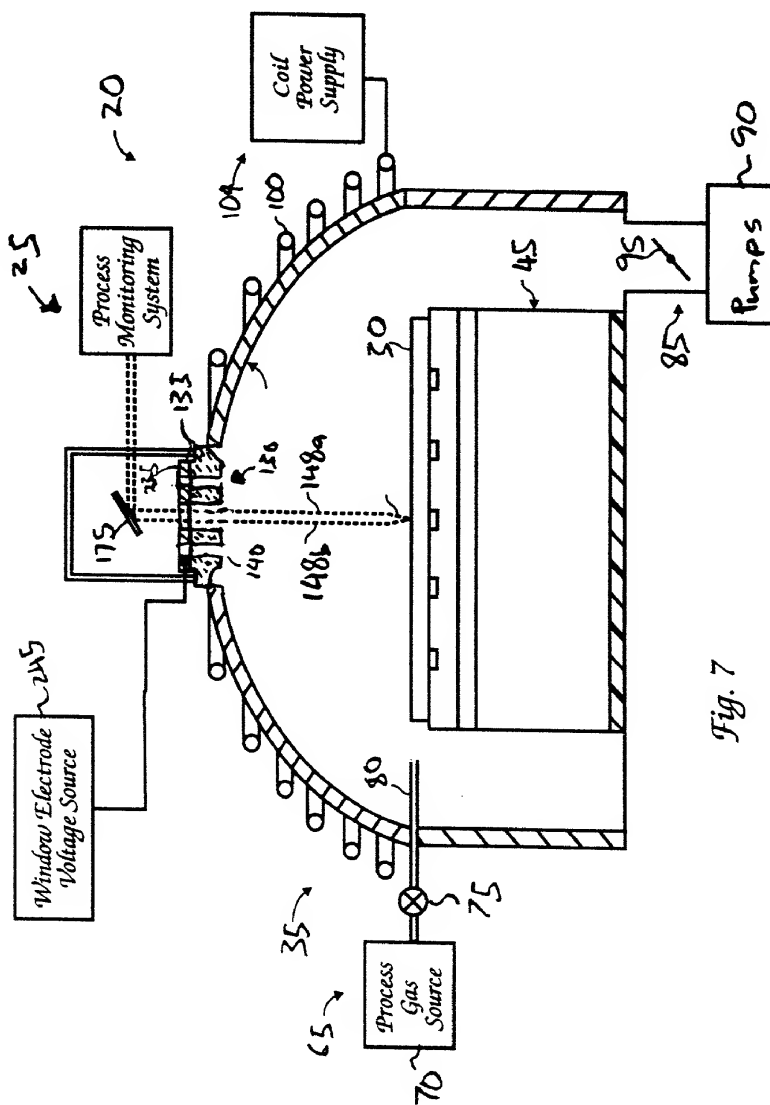
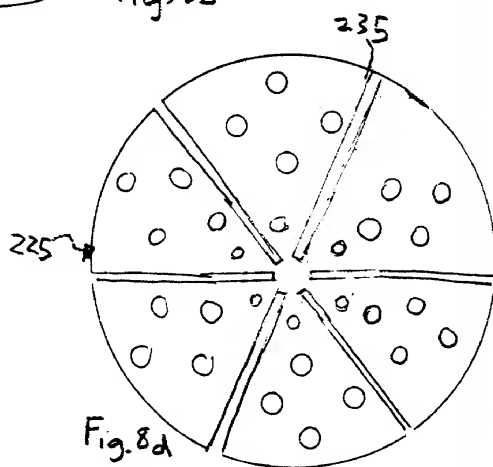
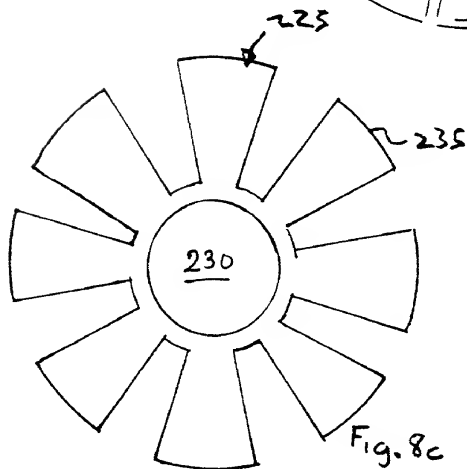
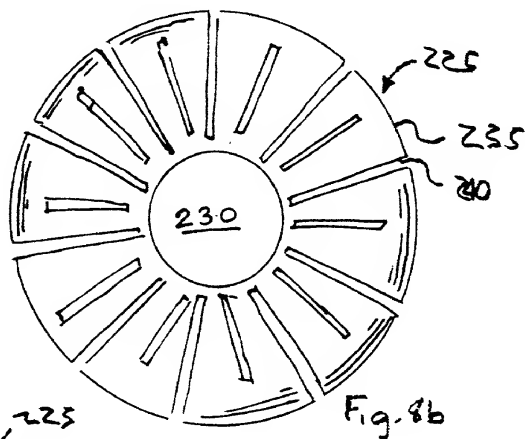
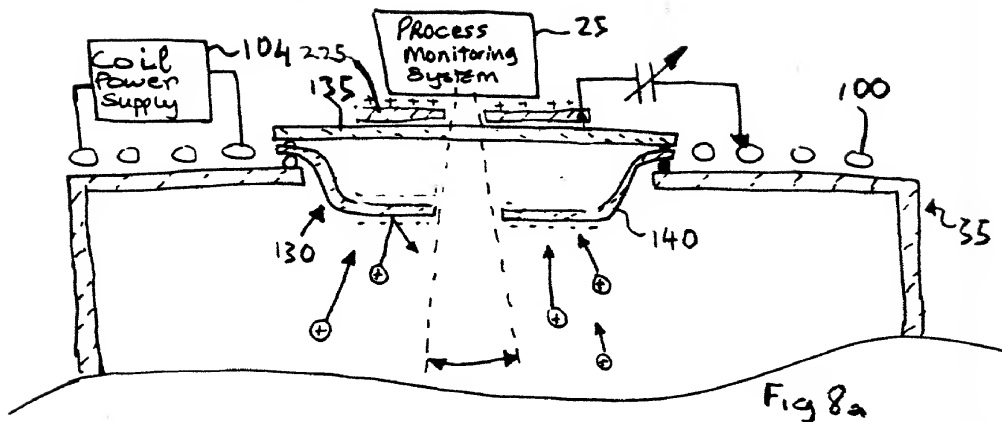


Fig. 6d

00540237 10700000 000000 22019560





COMBINED DECLARATION AND POWER OF ATTORNEY

As a below-named inventor, I hereby declare that:

This declaration is of the following type:

- ☒ original
- ☐ divisional
- ☐ continuation
- ☐ continuation-in-part

INVENTORSHIP IDENTIFICATION

My residence, post office address, and citizenship are as stated below next to my name. I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first, and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

TITLE OF INVENTION

"CHAMBER HAVING IMPROVED PROCESS MONITORING WINDOW"

SPECIFICATION IDENTIFICATION

The specification of which:

- ☒ was executed and filed on June 11, 1998, Serial No. 09/096,728.
- ☐ is executed and filed on even date herewith via
 - ☐ Express Mail No. _____ (as Serial No. not yet known)
 - and was amended on _____ (if applicable)
- ☐ was described and claimed in PCT International Application No. _____
filed on _____ and as amended under PCT Article 19 on
_____ (if any).

ACKNOWLEDGEMENT OF REVIEW OF PAPERS AND DUTY OF CANDOR

I hereby state that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended by any amendment referred to above.

I acknowledge the duty to disclose all information I know to be material to patentability in accordance with Title 37, Code of Federal Regulations, § 1.56, and which is material to the examination of this application; namely, information where there is a substantial likelihood that

a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent, and

- ☐ In compliance with this duty there is attached an Information Disclosure Statement in accordance with 37 CFR § 1.98.

PRIORITY CLAIM (35 U.S.C. § 119)

I hereby claim foreign priority benefits under Title 35, United States Code, § 119, of any foreign application(s) for patent or inventor's certificate or of any PCT international application(s) designating at least one country other than the United States of America listed below, and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date before that of the application(s) of which priority is claimed.

☒ No such applications have been filed.

☐ Such applications have been filed as follows:

- A. Prior foreign/PCT application(s) filed within 12 months (6 months for design) prior to this application, and any priority claims under 35 U.S.C. § 119:

<u>Country/PCT</u>	<u>Application No.</u>	<u>Date Filed</u>	<u>Priority Claimed</u>
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☐ Yes ☐ No

- B. All foreign application(s), if any, filed more than 12 months (6 months for design) prior to this U.S. application:

Country:
Application No:
Filing date:

CLAIM FOR BENEFIT OF EARLIER U.S./PCT APPLICATION(S) UNDER 35 U.S.C. § 120

I hereby claim the benefit under Title 35, United States Code, § 120, of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code, § 112, I acknowledge the duty to disclose information that is material to the examination of this application (namely, information where there is substantial likelihood that a reasonable Examiner would consider it important in deciding whether to allow the application to issue as a patent) which occurred between the filing date of the prior application(s) and the national or PCT international filing date of this application.

**PRIOR U.S. APPLICATION(S) FOR WHICH BENEFIT
UNDER 35 U.S.C. § 120 IS CLAIMED**

<u>Serial No.</u>	<u>Filing Date</u>	<u>Status</u>		
		<u>Patented</u>	<u>Pending</u>	<u>Abandoned</u>

(None)

POWER OF ATTORNEY

I hereby appoint the following attorneys and/or agents to prosecute this application and transact all business in the Patent and Trademark Office connected therewith:

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DECLARATION

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and, further, that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

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Inventor's signature: Michael N. Grimbegen Date: 8/1/98
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(Declaration ends with this page)